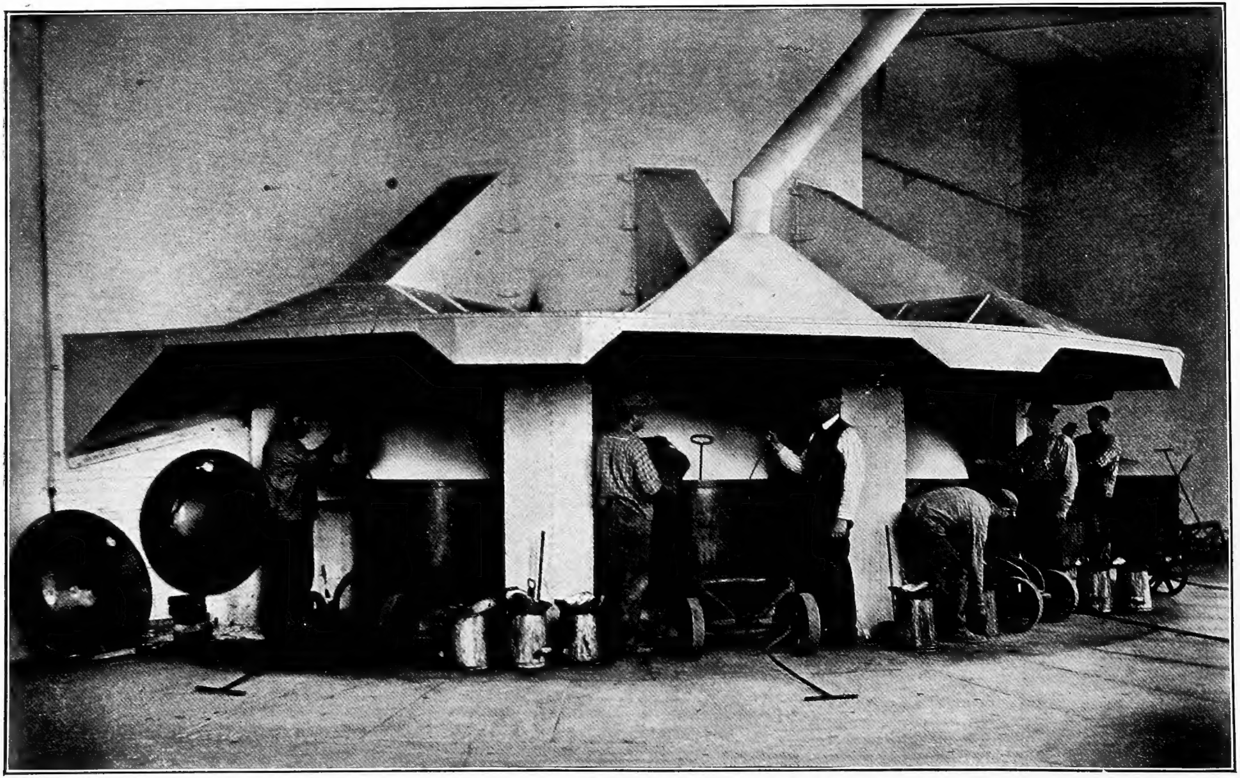

MELTING-ROOM.

By the courtesy of the Chicago Varnish Company.

THE
INDUSTRIAL AND ARTISTIC
TECHNOLOGY
OF
PAINT AND VARNISH.

BY
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SECOND EDITION, THOROUGHLY REVISED.
FIRST THOUSAND.

NEW YORK.
JOHN WILEY & SONS, Inc.
London: CHAPMAN & HALL, Limited
1917
E.V.

First Edition Entered at Stationers' Hall, London.

PRESS OF
BRAUNWORTH & CO.
BOOK MANUFACTURERS
BROOKLYN, N. Y.

PREFACE TO THE SECOND EDITION.

In the twelve years which have passed since the first publication of this work, certain changes have come about which seem to make a new edition desirable. The most important is the use of tung-oil in varnish-making, which has entirely changed the character of cheap and medium-priced products. Varnishes containing it dry with a rapidity and hardness unknown before, which lessens the time needed for finishing work; and its remarkable water-resisting quality makes rosin-varnishes more durable and better in every way. But surfaces thus finished become hard and crack; the general appearance of furniture and of railway passenger coaches and medium-priced carriages of every sort throughout the country has grown worse rather than better during the last ten years.

The writer is no longer in the varnish business, and feels more free to write in detail about it; and his connection with the National Lead Company, which makes white lead by several processes, also pure colors, mixed paints, linseed-oil, and in fact almost everything used in paints, has increased his knowledge of and interest in paint as distinct from varnish.

In this connection I wish to speak of my indebtedness to G. W. Thompson, chief chemist of that company, for valuable aid in this revision, as well as in all that pertains to paint problems in general

This book is nearly a third larger than its original; but the author asks the patience of the reader, because he has left out twice as much more which he would have liked to put in.

Flushing, N. Y., October, 1916.

PREFACE TO THE FIRST EDITION.

The wise Quintilian remarked, that "If we can say what is right we shall be delighted, though it may not be of our own invention." This observation may well serve as a text for any one who speaks of a technical art, such arts being of slow growth, so that an account of any of them concerns itself much with the past, and the knowledge of the expert, as a bookmaker, is largely valuable for separating the true and the significant from that which is untrue, or if true is of no relevancy or use. To no art does this apply more than to that which concerns the making and using of protective and decorative coatings, which have been used from remote times; sometimes, though perhaps empirically, in ways analogous or closely similar to the most approved modern practice, then wandering off into the use of inefficient, irrational, and unsatisfactory methods and materials.

The aim of the writer is to give a correct general outline of the subject of Paints and Varnishes, with a brief account of their modern use and of the principles which are involved in their fabrication and application. Many of the facts herein noted, though old, are practically unknown, and some of them exactly anticipate recently patented processes; their value to the public in that way is sufficient excuse for their republication. Scarcely any patents in this line are of any value or validity; and the "secret processes" which are continually vended are for the most part neither secret nor new. The only trade secrets lie in the incommunicable intimate knowledge of the expert, and are made valuable only by his unceasing care, vigilance, and conscientiousness. Theories may, however, be made known, and the attention of the student may be intelligently directed to their application.

The author foresees that one criticism of this work will be on the importance assigned to the use of oleo-resinous varnishes. He can only say in reply that if he had the courage of his convictions it would have been made a great deal more prominent than it is, and that the daily study of new problems, as well as systematic observation of the results of work done many years ago, produces in his mind the belief that it is in this direction we must look for future progress.

Apology is perhaps due the reader for the lack of a very coherent plan in this treatise. In part the contents of this book are those things which seem most interesting or important to the writer; in part they are things which long practical experience has shown to interest many other people. Things which many people will wish to know are left out, in many cases because of the limitations of the author's knowledge, but often because the book is already too large; and to all the writer commends the amiable maxim of Erasmus, that "a reader should sit down to a book as a polite diner does to a meal. The entertainer tries to satisfy all his guests; but if it should happen that something does not suit this or that person's taste they politely conceal their feelings and commend other dishes, that they may not distress their host."

FLUSHING, N. Y., August, 1904.

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CHAPTER I.

INTRODUCTORY.

WHEN we devote our attention to the subject of paint and painting, we seem to encounter matters on which the vast majority of commonly well-educated people feel almost entire ignorance and concerning which the opinion of any self-constituted expert is allowed to carry a weight which is out of all proportion, in most instances, to its real value. In reality, although there are many special cases where expert opinion is needed, and not a few where the most learned and practised must feel uncertain, the general principles involved are not difficult to understand, and should be known to any one who is interested in the practical matters of every-day life. The lack of such knowledge is a source of discomfort and unnecessary expense to not a few who are the victims of the ignorance and cupidity of those whom they employ. Very many people have a fair practical knowledge of carpentry, for instance, so as to be able to detect poor workmanship, although unable to do such work themselves; some have such a knowledge of plumbing; but few feel qualified to critically examine a job of painting and varnishing, yet almost everything which we touch or use has been in some way or some part treated with a protective or decorative coating.

The beginner, who will probably find this book more helpful and suggestive than any one else, since the author cannot hope to instruct the expert, must begin at the beginning, that is to say, with a brief description, correct so far as it goes, of the most essential materials and processes employed in the art, which having learned, discussion of more detailed matters may be understood and the consideration of the more complex or difficult compounds or methods will be left to later chapters. Let us consider, then, which first, paint or varnish? It is difficult to decide; like the celebrated problem of the bird and the egg: "When I consider the beauty of the complete bird," said the owl, "I think that must have been first, as the cause is greater than the effect; when I remember my own childhood, I incline the other way." Painting is not complete without varnish. Varnish is an ingredient of most paint, but paint is often thought of as the foundation and varnish as the finish. It does not matter much; let us tell first about varnish.

Varnish: Definition.—As the term is commonly used, this is a substance which is applied as a liquid, and on exposure to the air hardens and forms a thin and usually somewhat transparent film (but some varnishes are black and nearly opaque), which improves or better displays the surface over which it is spread and to a considerable degree protects it from dirt and injury. Some varnishes harden by a chemical change, which in almost all cases is the absorption of oxygen from the air, others by the evaporation of the solvent. The former are the most important and are made from certain resins, known as varnish-resins or varnish-gums (though not gums in the strict sense, but commercially so called), and linseed-oil. They are thinned with spirits of turpentine. The process of manufacture is briefly as follows:

Varnish: How Made.—The resin is put in a copper kettle, which is then put over a hot fire until the resin is thoroughly melted. The linseed-oil is then added and the mixture is heated until the ingredients are well combined. It is then partially cooled and is thinned with enough spirits of turpentine to make it thin enough for use when cold. When such a varnish is spread over a surface with a brush or otherwise it forms a thin film, not more than a few thousandths of an inch in thickness, and of course exposes a great deal of surface to the air. What first happens is that the turpentine evaporates, then the oil and resin compound absorbs oxygen and is converted into a hard, glossy film. This may take a few hours or a few days.

Upon a little reflection it will be obvious that the relative amounts of oil and resin will be an important factor in determining the quality of the compound; also, since the oil and turpentine are always of about the same quality, while the resins vary considerably, that the kind of resin used will be of importance; and that different sorts of varnishes may be made for different uses.

Spirit Varnish.—Varnishes of another kind are made by dissolving the resin (or other substance, but resins are chiefly used) in a volatile liquid such as alcohol. Such a varnish, when spread over a surface, loses its solvent by evaporation, and the resin is then found in a thin uniform film, the liquid having served as a mechanical means of uniformly spreading the resin over the surface to be coated.

Linoxyn.—If we spread a film of lard-oil or cottonseed-oil over a non-absorbent surface, such as a piece of glass, and expose it to the air, it does not seem to change, at least not for a long time. The surface is simply made greasy; but if we use linseed-oil in the same way, after a short time, or at most within a few days, we find that a remarkable change has taken place. The film is no longer a greasy fluid, but is a tough, leathery, solid substance, not in the least like oil. This new material has been formed by the absorption of oxygen by the oil and is known as oxidized oil, or linoxyn. This capacity for change into a tough and permanent solid substance by the action of the air is an unusual and valuable quality, which causes linseed-oil to be chosen for making paint or varnish. In fact, the film of dried oil without any addition of resin is a sort of varnish, and in some countries is commonly spoken of as oil varnish. Such a film is pale yellow in color, nearly transparent, like most varnish-films, and if it is desired to apply a colored film it is, of course, necessary to add some color to it.

Pigments.—This is done by mixing with the oil or varnish, while it is a liquid and before it has been spread over the surface to be coated, a colored pigment which is a solid substance, such, for example, as a piece of colored rock which has been ground to a fine powder. This pigment does not dissolve in the oil but only mixes with it, converting it into a muddy, opaque, colored liquid, of course of a thicker consistence than the pure oil or varnish.

Paint.—When this mixture, which is called paint, is spread out in a thin film the oil or varnish hardens, as has been described, and acts as a cementing material, or binder, to hold the particles of pigment on the surface which has been coated. But oil and varnish are not the only cements, and it is not absolutely necessary to use them in making a paint. We may mix the colored pigment with a dilute solution of glue, as is done in making kalsomine, and such a mixture is used in making water-color or distemper paintings.

Water-colors.—There is no reason why painting done in distemper (water-color) should not, after it gets quite dry, be varnished with any ordinary varnish, to enhance its beauty and make it more permanent, and in fact this is often done and has been from the earliest times.

Encaustic Painting.—In former times there was still another sort of painting, which has now gone out of practice, called encaustic painting. This was done with wax, colored by mixing it with suitable pigments, applied in a melted condition, and sometimes covered with a varnish. Wax in solution is still employed as a coating, especially for floors, but encaustic painting was done with melted wax and the finished work commonly glazed by holding a hot iron or a torch in front of it. Such painting was very durable when not exposed to heat nor to the weather, but could not be handled. It was used for mural decorations. Instead of a spirit varnish, a powdered resin was sometimes employed, which was sifted over the surface and fixed by being melted by the application of a hot iron. Sandarac was the resin used, and this was the old English pounce, sprinkled over the surface from a pouncet-box or pounce-box like a pepper-box. There are many other minor varieties of both paint and varnish, but if the reader will remember what has just been told, especially the practice of making oleo-resinous varnishes by first melting the resin and then adding the oil, cooking the compound, and afterward thinning it, he will be able to clearly understand the modifications and additions which are to be made in the later descriptions of a more detailed character.

CHAPTER II.

EARLY HISTORY.

KNOWLEDGE of the early history of any art is fragmentary and apt to be to some extent conjectural, but none the less interesting. It is, therefore, without apology that a few facts are here given, not as a complete or definite history, but only in a tentative way, as a possible nucleus about which other students with better opportunities may group a more systematic series of studies on a subject which appears to have received less attention than its importance and intrinsic interest deserve.

The use of both decorative and protective coatings is of great and unknown antiquity. Savages use both mineral and vegetable colors to decorate their persons, their clothing, and their abodes; anointing the body with oil as a protection against the weather is a common practice. Oil is also used on dressed skins of animals to make them pliable and water-proof, and temporary and permanent dwellings, and boats, are made waterproof by the use of fatty and resinous bodies. When Noah built the ark and coated the seams with pitch he was doubtless following the most approved system of use of protective coatings on structural materials, which was then probably of remote antiquity and traditional origin, and which he may have learned when he was a boy, four or five hundred years before.

Grease-paints.—It is only reasonable to suppose, and this is borne out by the present practice of savage tribes, that the earliest paints may have been pigments mixed with grease or fat. Such a paint adheres to the human skin with considerable persistence, yet it may be removed by thorough washing, and of this nature are the grease-paints still used by actors. This may fairly claim to be the oldest kind of paint. When such a paint is applied to leather or wood it is practically impossible to remove it and probably its protective action is considerable. The use of oil alone as a preservative, e.g., to make the wood of bows and lances water-proof, is perhaps a forerunner of varnish, being closely allied to the use of varnish on violins and other musical instruments.

Egyptian Varnish.—So far as is yet known to the author, the oldest varnish in existence is that on the wooden mummy-cases brought from Egypt. This is probably twenty-five hundred years old. The only chemical examination of this which has been published was made by Professor J. F. John, of Berlin, about 1822. Lieutenant-General H. Von Minutoli conducted an exploring expedition in Egypt, and published an account under the title "Reise zum Tempel des Jupiter Ammon, etc., nach Ober-Aegypten in den Jahren 1820–1821." In an appendix to this book (which may be seen in the New York Public Library) is a short paper by Dr. John describing this varnish, which he found to be insoluble in water, soluble in alcohol, and thrown down as a gummy precipitate by diluting the alcoholic solution with water. He concluded that it was a compound of resin with oil, but I infer that he meant a solution of resin in an essential oil, like oil of cedar, which is about the same as oil of turpentine, since some of the varnishes of the middle ages were of this sort (in fact they were the most common varnishes in Professor John's time), and he knew that the Egyptians were able to make oil of cedar in early times.

Turpentine.—Herodotus, who visited Egypt about 460 B.C., describes the use of oil of cedar for embalming. These more common essential oils were prepared both by the Egyptians and the Greeks before the invention of the still. One of the earlier methods was to put the crude turpentine in a pot and lay over the top of the pot some sticks which supported a fleece of wool. When the contents of the pot was heated, the essential oil condensed in the wool, from which it was squeezed out. A good account of the early methods and references to the ancient literature of the subject is to be found in Gildermeister and Hoffman's Volatile Oils, of which an English translation has been made by Dr. Kremers of the University of Wisconsin.

The varnish in question may be seen on mummy-cases in the Metropolitan Museum of Art in New York City. It is of a pale-yellow color, surprisingly free from cracks, very hastily and roughly applied, as though smeared on with a flat blade. This suggests that it may have been a compound of a resin and a fixed oil. We know that the ancients of all nations knew how to prepare vegetable oils, which were used as food, and also that they raised flax, and it is not unlikely that linseed-oil may have been used as a solvent for some of the African resins, which are to this day perhaps the most important varnish-resins. A varnish made with five or six parts of oil to one of resin without any essential oil as a solvent would, when warm, be applied exactly as the varnish on these mummy-cases was, would take, as that apparently did, a partial set on cooling, having practically no flowing quality, and would be extremely durable. No other varnish is known to the author which would behave in this way; yet this is largely a matter of conjecture, no samples being available for analysis. This much, however, is clear, that the Egyptians made a good durable varnish which has stood exposure to the air twenty-five hundred years and still looks well. If the varnish, as they made it, was a solution in oil of turpentine, there is no reason why it should not have been properly thinned, as it would then flow out under the brush, and it would also seem that it might have been used as a vehicle for painting, while in fact all their painting seems to have been done with pigments mixed in a solution of glue.

Glue Size.—This painting in size, or distemper, seems to be the oldest which has come down to us. In a dry climate it is very lasting; and the Egyptians were expert glue-makers, some of their glued wood joints having lasted three thousand years. I have been told by Mr. Hewitt (of the Cooper-Hewitt Company) that there exist descriptions on early papyrus rolls of the Egyptian methods of glue-making showing that they had the essential principles of the present methods, and made practically the same product as some of the best glue made now.

Wax Paint for Ships.—Much of the painting done by the Romans, as, for example, at Pompeii, appears to have been with size, or glue solution, as the vehicle, but they were also acquainted with encaustic painting, where the colors are mixed with wax. Pliny says that "when it became the fashion to paint ships of war, a third method was introduced of melting the wax with fire and using a brush. Paint applied to ships in this way cannot be destroyed either by the action of the sun or of the brine or wind." This sounds very much as though Pliny were copying from an early advertisement. It is curious to note, as will be shown later, that this method of applying a melted non-drying paint is still in extensive use on the exterior of ships, and almost nowhere else. Clarified beeswax was used in ancient times; with it were mixed coloring matters, and in this way were made paints which formed films of great thickness as compared with any ordinary paint-film and, being practically impervious to water, were very permanent when preserved at a uniform and not too high temperature.

Vernix.—In considering the history of this subject, it is first of all to be remembered that prior to the seventeenth century the word varnish (Latin, *vernix* or *vernisium*), was not primarily used to mean a liquid composition, but a dry resin, which when melted and boiled with linseed-oil formed a liquid called *vernice liquida* by the early Italian writers, and corresponded to our modern varnish. This use of the term is analogous to our use of the word glue, by which we mean primarily a dry substance and secondly the solution of the same ready for use. The resin has always been regarded as the essential and distinguishing component of varnish; even in the case of varnishes made from boiled oil alone, it is common to speak of the oil as being converted into resin.

Painters' Bills in the Thirteenth Century.—The fact that varnish was a dry resin is shown in many ways. For example, in the early English accounts of expenditures for the king, the

X

quantity of varnish is always noted by weight, and of oil by measure. In the period of 1274 to 1277, in the early part of the reign of Edward I., an account, apparently relating to the Painted Chamber, contains the following items:

To Reymund,	for seventeen pounds of white lead....	II s.	X d.
To "	" sixteen gallons of oil..........	XVI s.	
To "	" twenty-four pounds of varnish	XII s.	
To Hugo le Vespunt,	" eighteen gallons of oil...........	XXI s.	
To Reymund,	" one hundred leaves of gold.......	III s.	
To "	" twenty-five pounds of varnish.....	XI s.	I d.
To William, the painter,	and his helper, for the painting of twelve mews..................	XXXVI s.	
To " " "	for seven score and twelve pounds of green for the same............	LXXV s.	IV d.
To Stephen Ferron,	" twenty pounds of white..........	II s.	
To " "	" one gallon of honey.............		XII d.
Item,	" one gallon of white wine.........		III d.
"	" small brushes, and eggs..........		III d.
"	" yellow..........................		VI d.
"	" size...........................		XII d.

These accounts clearly show that dry substances were sold by the pound and liquids by ~~weight.~~ The use of honey, eggs, and size was for distemper painting, in all likelihood. So also in the records of the church of St. Jacopo at Pistoja, Italy, in 1347, is an expense for one pound of varnish, soldi VI.

These illustrations could be largely extended. The Italian writers on painting constantly speak of varnish and of liquid varnish as entirely distinct. It appears to be the common opinion of the early writers that the substance properly known as varnish was amber, which was the resin now known by that name, but was also applied apparently to some of the hard African resins which reached Europe, either through Egypt or from India. Formerly a considerable amount of Zanzibar resin reached India and was marketed from that country. Salmasius, the greatest classical scholar of the early part of the seventeenth century, says the term "vernix" was misappropriated to mean "sandarac," because of the resemblance of that resin to amber. Some of the dictionaries of the middle ages say that vernix is sandarac, and that it was a dry resin. They also define liquid varnish as the resin dissolved in oil. My own belief is that there have always been different kinds of varnishes, both the resins and the liquids, and that the best varnish was amber, the inferior being sandarac. The latter term included many resins which appear like it, and grade down to common rosin, which was used as varnish in very early times.

Incense.—These inferior resins were commonly spoken of as frankincense, or incense, which was also used as synonymous with varnish. Thus we read of the application of incense, or frankincense, to pictures as a finishing touch. Amber and similar resins have always been costly and rare, and there has always been a substitution for them of common and cheaper resins, either fraudulently or, more generally, as a cheaper but sufficiently good material. Certainly, from the present time back as far as we have any definite history of varnish, there always have been two well-defined grades, one made from hard resins, the other from those which are both cheaper and more easily manipulated. It is in fact interesting to notice how varnish recipes go in pairs, one for amber and the other for sandarac, among nearly all writers on the subject. It was an early practice, which has probably not yet become entirely obsolete, to sprinkle powdered resin over paper on which writings or drawings had been made. This served to fix the writing and was sometimes made more certain by the application of a heated iron. Sandarac, or some similar resin, was used for this purpose, and the hard resins like amber are not suited for such service. As this use of sandarac is of considerable and probably great antiquity, it is an illustration of the proper use of these softer recent resins. Sandarac, mastic, olibanum, and other similar resins come from northern Africa and western Asia and have, therefore, been known from most ancient times, and juniper resin, which is closely allied to sandarac and has been used for it, is very widely distributed.

Treatise of Theophilus.—The earliest important treatise of the middle ages on technology is the Schedula Diversarum Artium of Theophilus Presbyter, a German or Swiss monk.

There exist several MS. copies of this work, from which translations have been made, the most recent of which was by Dr. Albert Ilg of Vienna, 1874, by whom the various authorities and commentators have been carefully studied. Ilg thinks Theophilus wrote in the eleventh century. Lessing, who also studied Theophilus, regards him as belonging to the tenth century and to have been identical with Tutilo, a monk of the monastery of St. Gall, Switzerland. The name Tutilo, or Tuotilo, is said to be the same as Theophilus. Many monasteries of the middle ages gained celebrity by the skill of their artists, and that of St. Gall was especially distinguished in this respect, Tutilo and Notker, monks of this convent, being the most celebrated painters, sculptors, and gold-workers of their time in Germany. Tutilo was contemporary with the Abbot Salorno of St. Gall, and made for him a golden crucifix of wonderful workmanship. Ekkehard speaks of Tutilo as "mirificus aurifex." He was also musician, poet, orator, and statesman. The Emperor Charles the Thick complained that such a man should be shut up in a convent. However this may be, the treatise in question is not later than the eleventh century and it does not claim to be original, but to be a digest of standard and well-known methods and processes. It quotes largely from an earlier work of the same kind by Eraclius, and some of the recipes are in the Lucca MS. of the eighth century. Eraclius collected formulæ as far back as Dioscorides, early in the first century.

His Formula for Varnish.—Theophilus gives a formula for making varnish as follows:

Pone oleum in ollam novam parvulam et adde gummi quod vocatur fornis, minutissime tritum, quod habet speciem lucidissimi thuris, sed cum frangitur fulgorem clariorem reddit; quod cum super carbones posueris, coque diligenter sic ut non bul-

Put some linseed-oil into a small new jar, and add some of the gum which is called fornis (varnish), very finely powdered, which has the appearance of the most transparent frankincense, but when it is broken it gives back a more brilliant lustre;

liat, donec tertia pars consumatur; et cave a flamina, quod periculosum est nimis, et difficile extinguitur si accendatur. Hoc glutine omnis pictura super linita lucida fit et decora ac omnino durabilis. Compone quatuor vel tres lapides qui possent ignem sustinere ita ut resiliant et super ipsos pone ollam rudem, et in eam mitte supradictum gummi fornis, quod Romana glassa vocatur, et super os hujus ollæ pone ollam minorem, quæ habeat in fundo modicum foramen. Et circumlineas ei pastam, ita ut nihil spiraminis inter ipsos ollas exeat. Habebis etiam ferrum gracile manubrio impositum, unde commovebis ipsum gummi, et cum quo sentire possis ut omnino liquidum fiat. Habebis quoque ollam tertiam super carbones positam, in qua sit oleum calidum, et cum gummi penitus liquidum fuerit, ita ut extremo ferro quasi filum trahitur, infunde ei oleum calidum, et ferro commove, et insimul coque ut non bulliat, et interdum extrahe ferrum et lini modice super lignum sive super lapidem, ut probes diversitatem ejus; et hoc caveas in pondere ut sint duæ partes olei et tertia gummi.

which, when you have placed over the coals, cook carefully so that it may not boil, until a third part is evaporated; and guard from the winds because it is dangerous to a high degree and difficult to extinguish if it takes fire from the top. Every picture smeared over with this glaze becomes clear and beautiful and in every way durable. Set up four or three stones which are able to stand the fire so that they lean apart; on these place a common pipkin, and in this put the above-mentioned portion of the gum fornis, which is called Roman glassa (amber), and over the mouth of this pot set a smaller pipkin which has in the bottom a middling-sized hole. And around these put luting so that nothing may get out of the crevice between these pots. You should have, moreover, a slender iron rod set in a handle with which you may stir this mass of gum, with which you may feel that it is entirely liquid. You must have also a third pot set over the coals, in which is hot oil, and when the interior of the gum has become liquid, so that with the end of the iron rod it may be drawn out like a thread, pour into it the hot oil and stir it with

Cumque ad libitum tuum coxeris diligenter, ab igne removens et discoperiens, refrigerari sine.

the iron rod, and at the same time cook it so that it may not boil, and from time to time draw out the rod and smear it properly over a piece of wood or stone, that you may find out if there is separation; and see to this that in weight there be two parts of oil and the third of gum. And when, in your judgment, you have cooked it thoroughly, removing it from the fire and uncovering it, cool it out of doors.

In regard to the resin mentioned in this by the name of "glassa" it is proper to observe that Tacitus (De Moribus Germanorum, c. xlv) and Pliny (l. xxxvii, c. ii) both say this was the ancient German name for amber. It will be observed that nothing is said in the foregoing about thinning the varnish with spirits of turpentine. The varnish would contain 28 gallons (U. S.) of oil to 100 pounds of resin. It was to be warmed and smeared over the picture, using the fingers rather than a brush for this purpose. This practice was no doubt of great antiquity. It was the common practice in the time of Cennini, who said: "Place the picture level and with your hand spread the varnish well over the surface. If you do not choose to spread the varnish with your hand, dip a piece of clean sponge into the varnish and spread it over the picture in the usual manner" (ch. 155).

Formula from Alcherius, 1350.—Another old varnish formula is from Alcherius, who gives, under date of 1398, the following recipe, which was communicated to him by Anthonio de Compendio, then an old man, as an old and well-known formula:

"To make a good liquid varnish for painters: Take aromatic glassa, which is dark and dull outside and inside when broken is clear and shining, like glass. Put some of it into a new jar, on the mouth of which must stand another jar, which must be well luted to it. The upper jar must be well covered so as to be smoke-proof and its bottom must be pierced. Then light a fire beneath it and leave it until the glassa is melted, when you must take two parts of linseed- or hempseed- or nut-oil, and heat this oil slowly over a fire, not making it too hot. You must then pour it on the said glassa, make the fire hotter, and let it boil for an hour, taking care that the flame does not touch it. Then take it off the fire and put it into a clean vessel, and when you wish to varnish any dry painting take some of this liquid and spread it over the painting with your fingers, for if you were to do it with a pencil, it would be too thick and would not dry. You will thus have good varnish."

Formulæ from Jacobus de Tholeto, 1440.—About the same date are the following by Magister Jacobus de Tholeto, from the Bolognese MS. from the convent of S. Salvatore in Bologna, first half of the fifteenth century:

"S. 206. To make liquid varnish: Take of the gum of the juniper (sandarac) two parts, and one part of linseed-oil. Boil them together over a slow fire, and if the varnish appears too stiff, add more of the oil and take care not to let it take fire, because you would not be able to extinguish it, and even if you would extinguish it the varnish would be dark and unsightly. Let it boil half an hour and it will be done."

"S. 207. To make liquid varnish in another manner: Take one pound of linseed-oil and put it into a new glazed jar, and then take half a quarter of an ounce of roche alum in powder and an equal quantity of minium or vermilion ground fine, and half an ounce of incense, also ground fine. Mix all these ingredients together and put them into the oil to boil, stirring it with a stick, and when the oil is boiling, as it is likely to run over, have another glazed jar ready and put it by that which contains the oil, so as to catch the oil which runs over, in order that it may not run on the ground; and in this manner make it boil up three or four times, and each time pour back what has run over on that which is boiling in the jar. Having done this, set fire to the oil on the right-hand side with a lighted straw and let the oil burn on the upper part; so that the jar may not burn on the inside, on account of the too great heat, for otherwise the oil would smell unpleasant. When you light the oil with the straw, remove the jar from the fire, and let it burn while you can say three paternosters, then extinguish the oil with a wooden cover, putting it upon the jar, and when it is extinguished remove the cover in order to let the vapor escape, then put it back over the fire. Do this three times and it is done."

Formulæ from the Marcian MS., 1520.—A hundred years later, in the first part of the sixteenth century, we find in a MS. of the library of San Marco in Venice the following:

"S. 402. A most excellent, clear, and drying varnish proper for colors, both in oil-painting and the other kinds of painting: Take two ounces of clear and good nut-oil, one ounce of clear and good Greek pitch (colophony), and half an ounce of clear and good mastic. Grind the pitch and the mastic (separately) to a very fine powder, and place the oil in a clean glazed pipkin over a charcoal fire and let it boil gently until it is done sufficiently, i.e., until one-third has evaporated. Then put in the powdered pitch, a little at a time, mixing and incorporating it well. Afterward throw in the mastic in the same manner, and when it is dissolved take the varnish off the fire and strain it through a fine and old linen cloth."

"S. 404. A most excellent varnish for varnishing arquebuses, crossbows, and iron armor: Take of linseed-oil two pounds, sandarac one pound, Greek pitch two ounces. Boil the oil, then dissolve in it the other ingredients and strain through a much-worn linen cloth, and when you wish to use the varnish scrape and polish the work and heat it in a hot oven, because that is the best place to heat it, and when it is at a proper heat, i.e., when the varnish adheres to it firmly and does not blister from too great heat, then lay it on thinly with an instrument of wood, so that you may not burn your fingers, and it will make a beautiful changing color.

"And if you supplied the place of Greek pitch with naval pitch, I think it would make the work black when you varnished it.

"When making the varnish, you must boil it well, even to such a degree as to make it foam and bubble, if necessary, in order that it may be clear and thick."

"S. 405. An excellent common varnish, good for varnishing whatever you please: Take two ounces of clear and good linseed-oil and one ounce of clear and good Greek pitch; but two ounces of the latter will also make the varnish thicker and give it more body. Boil the oil over a slow fire and then put in the pounded pitch a little at a time, that it may incorporate well, and add a little roche alum previously burnt and powdered, and when it is incorporated and boiled sufficiently, i.e., when you try a little of it in your fingers and find that it is done, strain it and keep it. When it is used it will be beautiful and good, and if it is too tenacious you will dilute it with a little oil. And if you wish it commoner, so as to sell it at a larger profit, take ten ounces of oil to one of pitch; and if you use black pitch, it will be good for pommels of swords, spurs, and similar things."

The following is also from the MS. of San Marco: "Item—a varnish. Take one pound of linseed-oil, boiled in the usual way, and anoint the vessel with it while hot, and four ounces of powdered amber. Place it to dissolve with the bottle closed on the coals, and when it is nearly dissolved pour in the hot oil and stop it up. Afterward, at the proper time, when the whole is dissolved, stir in three ounces of alum. Dilute the varnish with the necessary quantity of naphtha, or linseed-oil, or spirit of wine, and use it warm. . . .

"Take one ounce of sandarac, ground to a very fine powder, and three ounces of clear nut-oil. Heat the oil in a glazed pipkin over a slow fire in the same manner as linseed-oil is boiled. Then add the powdered sandarac, a little at a time, until it is dissolved. Add to it also at the same time as much clear incense finely powdered as will impart a pleasant savor to the whole mixture, stirring it well that it may dissolve; and if you please, you may add also a sufficient quantity of burnt and powdered alum to have a sensible effect on the whole composition, and the addition of the alum will improve the varnish, if you stir it until it is dissolved. It should then be strained through a linen cloth and afterward exposed to the sun and dew until a sediment is formed, which should be separated by pouring off the clear varnish, after which it will be ready for use."

Formulæ from Rossello, 1575.—The following are from the Secreti of Timotheo Rossello, Venice, 1575: "To make liquid varnish: Take one pound of sandarac resin and four pounds of linseed-oil. Place the oil on the fire to boil; take another vessel for the resin, adding three ounces of oil, little by little; stir continually with a spatula and let the oil continue to boil till the whole is transferred to the vessel containing the varnish. Keep up a good fire for the said varnish and in order to know when the mixture has been boiled enough, and if it remains thick and somewhat firm the varnish is made. Then remove it from the fire and strain through a cloth.

"To make a superior liquid varnish: Take three pounds of yellow amber and six ounces of pulverized brick. Make a furnace with two orifices below, each orifice having bellows adapted to it. The fire, which should be of charcoal, requires to be great. Let there be an opening above; in this fit a glazed vessel which is to be luted to the opening so that the fire may not penetrate, for if it were to do so the ingredients would presently be in a flame. Place your amber in the vessel with as much of the oil as will cover it, then blow with a bellows and make a great fire till the amber dissolves. As there is great danger of fire, have a wooden trencher ready, wrapped round with a wet cloth, and if the varnish should catch fire cover the vessel with the trencher. Meanwhile boil in another vessel the remainder of the oil, making a moderate fire with the charcoal, but still taking care that the flame does not ascend. Let this oil continue to boil till it be reduced one-third. Then when the amber is dissolved in the small quantity of oil first mixed with it, as above described, throw in the remaining oil which you have heated to ebullition, and mix together for the space of five minutes, so as to incorporate all well. Then remove from the fire and throw in the pulverized brick above mentioned. Stir again a little, then cover the vessel, let the contents settle, and the varnish is made."

Mathioli, 1549.—Mathioli in 1549 said: "The juniper produces a resin similar to mastic, called (though improperly) sandarac. This, when fresh, is light in color and transparent, but as it acquires age it becomes red. With this resin and linseed-oil is prepared the liquid vernix which is used for giving lustre to pictures and for varnishing iron."

Formula from Libravius, 1599.—Libravius, in his Singularia, in 1599–1601, says: "Take three pounds of linseed-oil; of burnt alum, purified turpentine, and garlic, each half an ounce. Mix these in the oil and boil till it ceases to froth. Then take one pound of amber (succinum), place it in a vessel, the cover of which has an opening about the size of the little finger. Pour in a little oil. Melt the amber on a tripod and stir it with an iron rod inserted through the opening in the cover, to assist the liquefaction. When dissolved, mix with the oil before prepared and boil to the consistence of a varnish."

Caneparius, 1619.—The following is by Caneparius (Venice, 1619):

"The sandarac of the Arabs is called Dry Vernix. From this and linseed-oil is made the dark liquid vernix so well adapted for giving lustre to pictures and statues. It even adds splendor to iron and preserves it from rust."

Formula from Alberti, 1750.—Alberti (Magdeburg 1750), writing on amber, says: "Dissolve one pound of pulverized amber in an earthen vessel, on a charcoal fire. As soon as it is melted pour it on an iron plate and again reduce it to powder. Then place it in an earthen vessel, first adding linseed-oil already boiled and prepared with litharge. The solution is completed by the addition of spirits of turpentine."

The foregoing formulæ, which are selected from a great number known to the writer, give a fair idea of the knowledge of the art of varnish-making in the middle ages. The conclusion I have reached from a careful study of the whole subject, as far as the records are accessible to me, is that the best varnish was made from amber, or rather from what was called amber, the term being made, as the records show (but which are not included here on account of lack of space), to include certain hard varnish resins from the East. This varnish was made originally without spirits of turpentine or any other thinner, and in order to have it sufficiently liquid it was made with a large amount of oil, from twenty-five to fifty gallons of oil to the hundred pounds of resin (to put it in the terms of modern varnishes), well cooked and slow-drying. The oil was carefully refined, as will be described later, and probably was made drying with litharge and possibly with umber, but the painter expected to allow a long time for his work to dry, in some cases a year or more for the paint to dry before the final varnishing; and if haste was necessary, the use of an oven or other source of heat was the alternative. There was practically no progress for eight hundred years, the varnish made by Theophilus being quite equal to that made in the eighteenth century, and when a really good varnish was desired recourse was had to this old formula, which was handed down from one generation of artisans to another. There were no varnish-makers in the modern sense until the nineteenth century, i.e., no established business of varnish-making, but every important manufacturing establishment had its own varnish-maker, who made up small quantities, but the more important apothecaries in the large cities sold, and in some cases made, varnish; sometimes "common liquid varnish" only, which was made with sandarac or other cheaper resin; sometimes this and also amber varnish. But always small batches were made. Near the end of the eighteenth century Tingry, the most noted varnish-maker of his time, warns his followers that six ounces of amber is as large a melt as is advisable. It will further be shown that varnish was known before the Christian era, and there can be no reasonable doubt that knowledge of the art was continuous from at least as early as 500 B.C., when those varnishes were made which still exist on the Egyptian mummy-cases already mentioned, down to the present time, and it seems likely that the formula of Theophilus may have been handed down from those early Egyptian workmen. This latter conclusion may strike the reader as an unsupported conjecture; and since the matter is one of interest to all those who care to know about the origin of the art, it is worth while to give some of the grounds which seem to support such a proposition.

Varnish-making Probably Continuous from Egyptian Times.—In the first place, nothing is so conservative as tradition in artisanship. We still wear the buttons on our coat-sleeves which were used by our ancestors in the dark ages to fasten back their sleeves when they went into battle, and those on the backs of our coats with which they buttoned up their skirts to ride in the saddle. Hundreds of such instances are known to the student. Those who have not studied such things cannot imagine how persistent habits and methods of workmanship are. The fact that the process of Theophilus, which he put down as the old and approved one, continued for hundreds of years after his time and is still almost exactly practised, only with some additions and on a larger scale, a thousand years after it was known to the men who communicated it to him, is in reality a substantial reason for believing that it had then existed a long time. This is also strongly supported by the appearance of the Egyptian varnish. Too much stress cannot be laid on the fact that here we are not dealing with tradition or history, but with the real and actual thing. Here is the varnish, just as it was applied twenty-five hundred years ago. It is just as real as the mummy itself, and is just as absolute a proof that varnish was made in those days as the mummy is proof that people lived in those days. Here, I say, is the actual and real varnish. It was made with resin and oil. It was smeared on, possibly with a spatula, but more likely with the fingers, certainly not put on with a brush nor in a thinly fluid condition. Such a varnish as Theophilus describes would look as that looks, and in all probability would last as that has endured.

Materials Known to the Egyptians.—To the question as to whether the Egyptians knew of the materials we can say that obviously they had suitable materials and that there is no reason why they may not have been the same. As to resins, we know that for thousands of years the Egyptians had made warlike incursions into tropical Africa, whence come our best varnish-resins, and it is extremely probable that some commerce existed between those regions and Egypt; also that no resins native to northern Africa or Arabia are known to be as durable as these varnishes have shown themselves to be. The Chinese have from very ancient times imported varnish-resins from the East Indies which shows that resins are naturally objects of commerce, and the Egyptians were probably equally enterprising traders. It is very curious that they did not dilute their varnish with essential oil of turpentine, for this was really the substance known to Herodotus and later writers as "oil of cedar," which they used in considerable quantities for embalming purposes. It is equally singular that this was not practised by Theophilus, nor for three or four hundred years after his time, but such is the undoubted fact, and it bears out the hypothesis that the formula, perhaps of immeasurable antiquity, had been found to give satisfactory results and no modification of it was allowed. We do not know that the Egyptians used linseed-oil, or knew it, but we do know that they used linen and cultivated the flax-plant and therefore saved and stored linseed. We also know that they knew and used olive-oil, which is of remote antiquity, and hence must have had oil-presses. We also know that linseed-oil was in early times extracted with an olive-oil press, for Theophilus gives the following directions:

Formula from Theophilus for Making Linseed-oil.—"Take linseed and dry it in a pan, without water, on the fire. Put it in a mortar and pound it to a fine powder. Then, replacing it in a pan and pouring water on it, make it quite hot. Afterward wrap it in a piece of new linen; place it in a press used for extracting the oil of olives, or of walnuts, or of the poppy, and express this in the same manner."

If the Egyptians had for thousands of years been familiar with linseed and with the oil-press (as they were), it is not unlikely that they had put the two together. Pliny, who wrote about the beginning of the Christian era, says (l. xiv, c. 25): "Resina omnis dissolvitur oleo"—oil dissolves all resins. Dioscorides, who was before Pliny, describes walnut- and poppy-oils. Hippocrates, who lived in the fifth century B.C., recommends linseed poultice. Galen, who lived in the second century A.D., says that linseed is in its nature drying. Walnut- and poppy-oils are also drying oils, and one of these may have been used, but there is no reason to think that they were used before linseed, except that they are better suited, especially walnut-oil, to be used for food. Fresh walnut-oil is nearly as good as olive-oil, but it is to be remembered that at the present day in Russia linseed-oil is used as food.

Use of Varnish by Apelles.—Apelles, who lived in the fourth century B.C., was the court-painter of Alexander the Great. Pliny (l. xxxv, c. 18) says of him: "No one was able to imitate one thing, in that he spread the varnish over his completed work so thin that it brought out the brilliancy of the colors by reflection and protected it from dust and dirt." Also Cicero (ad Divers, l. 9, § 36) says: "Apelles finished the head of Venus with the highest polish." The picture of Venus was one of his most celebrated works. Praxiteles was a Greek sculptor who lived in the fourth century B.C. and who employed Nicias, a painter, to tint and varnish his statues.

By Nicias.—In book xxxv, ch. 28, Pliny says: "It is Nicias of whom Praxiteles, being asked which of his marble statues he most valued, answered, those to which Nicias had put his hand; so much care he had taken in rubbing them." The word here translated "rubbing" (circumlitioni) has the peculiar meaning of smearing on with a rubbing motion, and the passage indicates that the varnish was applied with the hand and polished by rubbing, in the way described 1400 years later by Theophilus. Protogenes was another Grecian painter, whose picture of Jalysus was his most celebrated work, and it appears from the following passage from Cicero that, like Apelles, he polished his paintings: "And as I believe Apelles and Protogenes saw with grief, the one his Venus, the other his Jalysus, covered with dirt; so I cannot without extreme distress see so strangely disfigured a man whom I have painted and polished with all the colors of art." (Cic. ad. Att., lib. 2, Epist. 21.) This passage may have suggested the following to Lord Bacon: "The fame of Cicero had not borne her age so well, if it had not been joined with some vanity. Like unto varnish, which makes ceilings not only shine, but last."

Poetical References to Varnish by Leonidas.—In the early part of the third century B.C. there was a Greek poet named Leonidas, who is best known by dedicatory verses and inscriptions on works of art. One of these short poems, on a picture of Eros—is here given:

Τοξοβόλον τον Ἔρωτα τὶς ἔξεσεν ἐκ λιβανώτου,
Τὸν ποτὲ μήδ' ἀυτοῦ Ζηνὸς ἀποσχόμενον;
'Οψὲ ποδ' Ἡφαίστῳ κεῖται σκοπός, ὸν καθορᾶσθαι
Ἔπρεπεν, ὀυκ ἄλλως ἢ πυρὶ τυψόμενον.
Anthol. Grec., Epig. lib. I, cap. xxvi.

Translation:

"Who has polished with the resin of incense this Eros armed with arrows, who does not respect Zeus himself?
At last behold him placed as a mark for Hephaistos, seen to be consumed by fire."

Another somewhat similar passage, also an inscription on a painting, shows in like manner that varnish was either the medium or the characteristic surface of the picture:

Μή με τὸν ἐκ λιβάνοιο λέγε ξένε, τον φελοκώμων
Τερπόμενον νυχίοι; ἠϊθέων ὀάροις,
Βαιὸς ἐγὼ νύμφης ἀπὸ γείτονος ἀγριώτης,
Μοῦνον εποτρύνων ἔργα φυτοσκαφίης.
Ἔνθεν ἀπ' ἐυκάρπου με φίλης ἔϛεψαν ἀλωῆς
Τέσσαρες ὠράων ἐκ πισύρων ϛέφανος.

A translation of the beginning of this is as follows and is addressed to the painter:

"Friend, no more remind me with resin of incense (i.e., varnish) how a depraved youth passed the time in riotous orgies," etc., and goes on to tell how he has adopted good habits, etc. The remainder of the poem indeed is like an order for another picture, showing the youth in good company, laboring in his orchard, interested in the changing seasons.

Still another Greek verse, on the picture of a maiden, with the same reference to the use of varnish:

> Οὔνομ' ἔχεις λιβάνου, Χαρίτων δεμας, ηθεα Πειθοῦς
> Παρθένε, καὶ Παφίης ὑπὲρ λαγόνων.

Translation:

> "Maiden, thou hast celebrity from the resin (varnish); to it thou owest thy form of the Graces, thy eloquence, and around thy waist the girdle of Venus."

In all the foregoing the same word (λιβάνον) is used, which has been rendered resin, or resin of incense. It is the word from which comes our word olibanum, which is the name of the resin of frankincense, but was used to denote any or all of the incense-resins, which were used for making the commoner kinds of varnish. It appears to have sometimes been the custom to apply these resins in the form of a powder which was then melted by holding a hot iron or a torch near them, after which the surface could be polished by rubbing. Eastlake, who appears to have studied this subject carefully, thinks that the pigments used were mixed with melted wax and applied with a brush. When cold, the surface was remelted to produce an apparently enamelled surface. This was enhanced by mixing resin with the wax to harden it, or by adding resin to the surface, which formed a varnish. This was in the case of encaustic painting; distemper painting could be treated somewhat in the same manner, or varnished in the ordinary way. It was evidently possible to get in some such way an extremely high lustre on encaustic (wax) paintings, as is illustrated by the following verse from the Greek anthology:

> Ἄρεα καὶ Παφίην ὁ ζωγράφος ἐς μέσον ὀίκου
> Ἀμφιπεριλέγοηην γέγραφεν ἀμφοτέρους
> Ἐκ θυρίδος δὲ μολὼν Φαέθων, πολυπάμφαος ἀίγλη,
> Ἕϛη ἀμηχανόων ἀμφοτέρους σκοπέων.
> Ἠέλιος βαρύμηνις ἕως τίνος; ὀυδ' ἐπὶ κηροῦ
> Ἤθελεν ἀψύχου τον χόλον ἐξελάσαι.

Translation:

> "A painter represents Mars and Venus in the middle of a temple. The sun, shining in through the doorway, scatters rays of the most dazzling brilliancy. The painter stands in astonishment and, looking at the two, he wonders if the sun is angry, or wishes to throw his wrath on the inanimate wax."

Vitruvius on Polishing Varnish.—That varnish was polished by rubbing is also indicated by the following from Vitruvius (l. vii, c. 4): "In his vero supra podia, abaxi ex atramento sunt subigendi et poliendi cuneis silaceis, seu miniaceis interpositis." "Among these panels over the balcony the wainscoting is rubbed and polished with varnish, with ochre or minium interposed."

The use of wax except as a floor-varnish has almost ceased, but with that exception there is nothing in all these passages which indicates any change of importance from the earliest times down to what we may call the historic period of varnish; and if the various practices of using varnishes have been the same, and if all we can learn of the composition of them seems without change, it would seem not unreasonable to suppose that the processes of varnish-making have also been handed down, without important variation, from at least the time when the varnish on the mummy-cases was made, i.e., about twenty-five hundred years. The most likely criticism is that, as varnishes made now do not last but a few years, it appears that we have lost the art known to the ancients. I reply, we have not lost the knowledge, but we have lost the patience necessary to the use of the most permanent and durable preparations. This will be clearly illustrated in a later chapter.

CHAPTER III.

VARNISH: ORIGIN OF THE NAME.

In the middle of the third century B.C. Berenice, whose grandfather was a half-brother of Alexander the Great, a very beautiful golden-haired woman, one of whose descendants was the famous Egyptian queen Cleopatra, was Queen of Cyrene and wife of Ptolemy Euergetes, King of Egypt. Not long after her marriage the king, her husband, engaged in a long and highly successful campaign in Asia, during the time of which the queen offered up prayers for his successful return, vowing to sacrifice her beautiful hair on the altar of Venus if the king should come back in safety. This she accordingly did; but the shining and jewelled tresses disappeared during the night from the altar, and it was found by the astronomer Conon that the deities had carried them to heaven, where they form, in the Milky Way, the constellation still known as the Coma Berenices, or Berenice's Hair. The poet Callimachus celebrated them in Greek verse as

> "The consecrated spoils of Berenice's golden head";

and Catullus, telling of the rivalry between Venus and Juno, says that

> "The winged messenger came down
> At her desire, lest Ariadne's crown
> Should still unrivalled glitter in the skies;
> And that thy yellow hair, a richer prize,
> The spoils devoted to the powers divine,
> Might from the fields of light as brightly shine."

When to the Greeks was brought from the far-off shores of the unknown Northern Sea the yellow translucent mineral we know as amber, they likened it to the sacred yellow locks of the beautiful Grecian woman, the first queen in her own right of the Macedonian race, and called it by her name, Berenice, and by this name it was known both to the Greeks and Romans for several centuries. "Amber" was an adjective not infrequently applied to the hair of fair women. The Emperor Nero, who sometimes affected to be a poet, wrote verses to the amber hair of his empress, Poppœa; in consequence of which, observes Pliny (l. xxxvii, c. 12), amber-colored hair became fashionable in Rome; and before this Ovid (Metamorphoses, l. xv, 316) said, "Electro similes faciunt auroque capillos"—"Her hair was like amber and gold." Because of its beauty, amber has always been a poetic simile. An ancient Persian poet says:

"But clear as amber, fine as musk,
Is Love to those who, pilgrim-wise,
Walk hand in hand, from dawn to dusk,
Each morning nearer Paradise."

The word Berenice is equivalent to Pheronice, literally meaning "bringing victory." Ph (ϕ) is changed to B in some Greek dialects, even in classic Greek, and B was in some dialects pronounced like our V, as it now is by modern Greeks, and as it was in the middle ages. Hence the word Berenice, meaning amber, was often written Verenice in Latin, and when we get down to the twelfth century we find in the Mappæ Claviculi the word spelled in the genitive verenicis and vernicis. This is probably the earliest instance of the Latinized word nearly in its modern form, the original nominative vernice being afterward changed to vernix, when comes our word varnish. The German name for amber is Bernstein, or Berenice's stone, and the Spanish word for varnish is Berniz, nearer to the Greek than our own word, which comes through the later Latin. Veronice, or Verenice, is the common name for amber in the MS. of the middle ages. Eustathius, a twelfth-century editor of Homer, says that the later Greeks called Electron (amber) by the name of Beronice; and Salmasius writes it Berenice and Verenice. In the Lucca MS. (eighth century) Veronica is often mentioned as an ingredient of liquid varnish, and this latter word, Veronica, is the modern equivalent of the name Berenice. Saint Veronica, however, had nothing to do with Berenice, but perhaps she might be adopted as a patron saint by the varnish-makers. Her sanctity does not appear to be of the highest order, since the observance of her festival is not obligatory.

Such is the origin of the word varnish. It was originally equivalent to amber, and amber is a type of the highest class of resins used in the art. The early Greek word for amber was elektron, from the verb elko, meaning to draw, because amber when rubbed becomes electrical and draws straws and other light objects to itself, whence also the word electricity. The Arabic and Persian term for amber is Karabe, from Kahruba, meaning straw-stealing, and Buttman states that the word Raf or Rav, meaning to seize, is the name for amber in the north of Germany.

Salmasius says that the word vernix was misappropriated to mean sandarac, because of the resemblance of that resin to amber. After the sixteenth century the term vernix ceased to be applied exclusively to the dry resin, and was used, as it is now, to mean the liquid compound.

Glassa.—As has already been mentioned, both Tacitus and Pliny say that the Germans of their time called amber by the name of glessum or glassa, which is supposed to be the original of our word glass. Tacitus believed amber to be the juice of a tree, because they find insects in it. Thus it is, he says, that in the Orient there are trees from which trickle frankincense and balsam, which made him suppose that there are in the west regions and islands where the sun draws from certain trees a sap, which, falling into the sea, is by it thrown up, hardened, on the shore.

Copal.—Another word which is of common use in this connection is copal. This is a comparatively modern word, and is from the language of some of the aborigines of Spanish America, commonly said to be Mexican, and is said to signify any kind of resin exuding from trees. The earliest writer who mentions copal by this name as an ingredient of varnishes is probably Fra Fortunato, of Rovigo, the recipes in whose "Secreti," date from 1659 to 1711. The next author is Calomino, who gives a recipe for varnish composed of copal dissolved in spirits of turpentine (see the Pharmaceutical Journal, Vol. IV, p. 4). As now used, copal is a generic term, including about all the varnish resins which are commonly combined with oil, and is not sufficiently definite to be used by varnish-makers. Copal varnish is a trade name, usually for a very inferior article made of common rosin, or colophony, and containing no copal; somewhat as the word "café" is used on the windows of grog-shops. In former times "amber" seems to have been used somewhat in the same way as "copal" now is, but was restricted to the hard and valuable resins; besides which there always was a specific substance known by that name, being the same that we now call amber, a yellow or red resin from the shores of the Baltic. Amber has almost passed out of use as a varnish-resin. The larger pieces are used for mouthpieces for pipes, and the smaller pieces are, it is said, cemented together to make larger ones. It is said to be difficult to melt, but the writer has not found this to be the case. It does, however, make a dark varnish and appears to be too costly to be much used. The fact that genuine amber, when polished, retains its surface longer than any other resin may indicate that the varnish made from it is of a high degree of permanence. It is commonly so with the other resins.

CHAPTER IV.

LINSEED-OIL.

VEGETABLE OILS have, from the earliest times, been extracted from the oil-bearing substance by the aid of a press; but while this is the most economical and efficient way, as shown by the fact that it is the modern method, it is not the only one. To get an idea of the way processes and practice were handed down, and how independent artists and artisans were of manufactured products, each producing for himself all that he needed, thereby being sure of its quality, it may be well to see what was the manner of apprenticeship prescribed by Cennini, who wrote the first treatise on painting which has come down to us, and which describes his own experience in the fourteenth century:

"Know that you cannot learn to paint in less time than that which I shall name to you. In the first place, you must study drawing for at least one year; then you must remain with a master at the workshop for the space of six years at least, that you may learn all the parts and members of the art—to grind colors, to boil down glues, to grind plaster, to acquire the practise of laying grounds on pictures, to work in relief, and to scrape or smooth the surface, and to gild; afterwards, to practise coloring, to adorn with mordants, paint cloths of gold, and paint on walls, for six years more—drawing without intermission on holydays and workdays. And by this means you will acquire great experience. If you do otherwise, you will never attain perfection. There are many who say that you may learn the art without the assistance of a master. Do not believe them; let this book be an example to you, studying it day and night. And if you do not study under some master, you will never be fit for anything, nor will you be able to show your face among the masters."

Bearing in mind the foregoing, it is interesting to see how oil was prepared in the laboratory of Leonardo da Vinci, the greatest painter of his time, in the fifteenth and sixteenth centuries. The recipe was found in his own handwriting and describes the process of making oil of walnuts, which, on account of its pale color, has always been a favorite with artists.

Oil-extraction in the Fifteenth Century.—"The nuts are covered with a sort of husk or skin, which if you do not remove when you make the oil, the coloring matter of the husk or skin will rise to the surface of your painting and cause it to change. Select the finest nuts, take off the shells, put them into a glass vessel of clean water to soften until you can remove the skin, change the water, and put the nuts into fresh water seven or eight times, until it ceases to be turbid. After some time the nuts will dissolve and become almost like milk. Put them then into a shallow open vessel in the air and you will soon see the oil rise to the surface. To remove it in a pure and clean state, take pieces of cotton, like those used for the wicks of lamps; let one end rest in the oil and the other drop into a vase or bottle, which is to be placed about the width of two fingers below the dish containing the oil. By degrees the oil will filter itself, and will drop quite clear and limpid into the bottle, and the lees will remain behind. All oils are of themselves quite limpid, but they change color from the manner in which they are extracted."

The foregoing is a good illustration of the manner in which oils are extracted by water without pressure. It is to be remembered that in the most modern practice of oil-pressing it is customary to moisten the ground seed with water or steam, showing that water seems necessary to start the separation of the oil from the solid part of the seed, probably by swelling and softening the tissues so that the oil can escape. In the multitudinous recipes of the middle ages there are many which show how universal was the belief, or knowledge, that water was essential to the separation or purification of oil. The most common method of purifying linseed-oil consisted in mixing the oil in a large vessel (large in proportion to the amount of oil used) with its own volume, or more, of water. This was heated until the water boiled, which of course helped to mix the oil and water, so that the latter might dissolve out the soluble ingredients of the former. As the water evaporated it was replaced from time to time, and after boiling for one or two or more days the mixture was allowed to settle and the oil poured off. This method was further complicated by the addition of salts of various kinds to the water.

Separation from Water.—When oil is treated in this way part of it is likely to remain as a persistent emulsion with the water. The common way of separating these emulsions is now to add common salt, which makes a brine of the water, and this brine separates easily from the oil; and cloudy oil is easily cleared by filtering it through or shaking it with some soluble saline substance, previously made anhydrous by heating it, which takes out the traces of water which produce the cloudiness. White vitriol (sulphate of zinc) is well suited for this purpose, and all the older recipes which recommend this salt say that it should first be calcined. Green vitriol (sulphate of iron) has also been used, but not so much.

Driers.—When zinc sulphate or any such calcined salt is used in this way to remove water, it is literally a drier. It makes the oil dry, in the sense that it frees it from water, and I cannot doubt that it was in this way that zinc sulphate came to be spoken of as a drier. Of course, oil which has in this or any other way been freed from water will oxidize, and in that sense also dry, faster than that which contains water, and so white vitriol and other hygroscopic salts came to be spoken of as driers and confused with that other class of driers, of which litharge is a type, which do not absorb water, but cause oil to dry or harden by increasing its chemical activity, a function which the zinc salts (and other similar substances) do not appear to possess in the least degree. Even with the most improved methods a great deal of the freshly pressed oil is turbid with water and wet matter, and is purified by long settling in tanks, followed by filtration.

It is easy to understand that in the laboratory of the painter, where only a pint or two of oil was made at a time, it was easier to clear it rapidly by treating it with a chemically inactive but hygroscopic salt. From this it was but an easy step to regard the saline substance as having a beneficial action on the oil itself. The use of these things, such as the sulphates of iron, zinc, and magnesia, and some other similar substances, has not yet become entirely obsolete, although in the way they are used they are probably absolutely useless.

"Breaking" of Oil.—It has long been known that if freshly made linseed-oil is heated, without the addition of any other substance, to about 400° F., it is decomposed; a considerable part of the oil appears to be converted into a gelatinous substance. This has been investigated by G. W. Thompson (Journal of the American Chemical Society, 1903), who arrives at the following conclusions:

Although the amount of gelatinous matter appears large, really but a small proportion, less than a third of one per cent. of the original oil is actually changed; but this is in bulky masses or lumps, swollen by the absorption of a large amount of the unchanged oil, which may be washed out of it by the use of solvents. When this is done and the decomposed oil is analyzed it is found to contain nearly half its weight of mineral matter, consisting of pyrophosphates of lime and magnesia, and amounting to practically all the mineral matter present in the original oil. As it has been often claimed that mucilage is contained in raw oil and is the cause of its "breaking," this was carefully looked for in the separated portion, but none was found; neither was there any nitrogenous matter. It seems certain that albuminous and mucilaginous matters are not contained in clear, well-settled oil.

The fact that the "break" of linseed-oil is due to the phosphates it contains explains the well-known method of refining oil for varnish-makers by treatment with a little acid, which decomposes and removes these inorganic constituents. Treatment with alkali will also do it; and oil which has been moderately heated and has had air blown through it will not break. This latter method has been used by the English varnish-makers for many years.

Linseed-oil is a yellow or sometimes greenish-yellow liquid. It is not known whether it is colored by some foreign matter contained in the seed or whether the pure oily matter has color of its own. Nearly all books which treat of it give recipes for bleaching it so that it shall be colorless, but it may be confidently asserted that no one ever saw any water-white linseed-oil, not so much as an ounce.

Bleached Oil.—"Colorless" linseed-oil is simply that which has been bleached to a pale-yellow color by some of the means known to oil-refiners; usually about half the color seems to be removed. All colored vegetable oils are bleached when exposed, especially in a thin film, to the sun. When linseed-oil which has been bleached in this way is put in the shade its color comes back, at least to a considerable degree. When it is heated to a high temperature, especially if at the same time agitated with air, so as to promote its oxidation, it is decomposed into a sticky, gelatinous solid, somewhat translucent, dark yellow or brownish yellow in color. This is soluble in caustic soda, making a soap, but a soap very different in its qualities from ordinary linseed-oil soap, showing that the composition of the oil has undergone a radical change. When oil is exposed to the air at the ordinary or at a moderate heat, and especially if in a thin film, or if air is blown through it, it is changed into a tough substance, quite elastic, somewhat like leather, though not nearly so tough.

Linoxyn.—This oxidized oil, or linoxyn, is a very insoluble substance. It resists ordinary solvents and weak acids, but is easily attacked by strong acids and by alkalies in all degrees of strength. When about half oxidized it is soluble in the usual solvents for oil—spirits of turpentine, benzine, ether, etc.

As to historical records, while, for reasons already given, the writer has no doubt of the use of linseed-oil from early times, we have no unmistakable mention of linseed-oil earlier than the fifth century, when it is incidentally mentioned by Aetius, a

Greek medical writer. It is interesting to note that Aetius gives directions for making walnut-oil, saying that it "is prepared like that of almonds, either by pounding or pressing the nuts, or by throwing them, after they had been bruised, into boiling water. The medicinal uses are the same, but it has a use besides these, being employed by gilders or encaustic painters, for it dries and preserves gildings or encaustic paintings for a long time."

Walnut-oil was not by any means new in his time, however, for it, as well as poppy-oil, is described by Dioscorides five hundred years earlier. The fact that these common things are not mentioned in such historical or literary writings as have come down to us is, therefore, not to be taken as an indication that they were unknown. Dioscorides describes a method of bleaching oils which will bear comparison with anything we do now.

Dioscorides on Bleaching Oil. — "Oil is bleached in this manner: Select it of a light color, and not more than a year old; pour about five gallons into a new earthenware vessel of an open form, place it in the sun, and daily at noon dip and pour back the oil with a ladle, beating up its surface till by constant agitation it is thoroughly mixed and made to foam. It is thus to be treated for several days. If it be not sufficiently bleached place it again in the sun, repeating the above operation until it becomes colorless."

In the "Secreti" of Alessio, prior of the Gesuati of Florence, the author of which was born in 1475, but which contains recipes of earlier date than 1350, are directions for refining oil by washing it with water.

The use of driers, especially of litharge, is probably of great antiquity. Galen, in the second century, who speaks of the drying character of linseed and hempseed, also says that litharge and white lead are drying in their nature. Marcellus, in the fourth century, gives directions to "put some oil in a new vessel and put it over a moderate fire; then add well-ground litharge, sprinkling it little by little with the hand. Stir it constantly till the oil begins to thicken."

Eraclius, who was certainly earlier than Theophilus, since much of his MS. was included by the latter in his writings, speaks of white lead as a drier for linseed-oil and gives the following directions: "Put a moderate quantity of lime into oil and heat it, continually skimming it; add white lead to it, according to the quantity of oil, and put it in the sun for a month or more, stirring it frequently. And know that the longer it remains in the sun the better it will be. Then strain it and distemper the colors with it."

Earliest Use of Umber. — In the De Mayerne MS. (which will be spoken of later) there is a letter from Joseph Petitot of Geneva, brother of the celebrated enameller, dated 1644, in which it is said that the ordinary drier for drying oils was umber. As the drying of umber is due to manganese, this is probably the earliest mention of manganese as a drier. The De Mayerne MS. also speaks of burning off oil to make it siccative, a practice still followed, especially in making printers' ink. It may be that this latter practice was known to the early varnish-makers, for they constantly speak of boiling oil until it is reduced in volume a third or a half, which might perhaps be done by burning off; while it is, if not impracticable, certainly never attempted in any other way at present. There is good reason for thinking that lead and manganese oxides, used as driers, act by absorbing oxygen from the air, thus making peroxidized compounds, then giving up a portion of this oxygen to the oil, then re-absorbing more oxygen, and so on. Thus a small amount of lead and manganese may serve to oxidize a large amount of oil.

Manganese Advised by Faraday.—It is said on what appears to be good authority that the use of manganese compounds for this purpose was first recommended, and on purely theoretical grounds, by Professor Michael Faraday, because manganese, like lead, exists in two states of oxidation, and readily passes from either of these to the other.

Cobalt and Nickel Driers; Vanadium.—There are but two other metals which possess this property, viz., cobalt and nickel, and the writer of this has found it possible to make most excellent driers with both these metals; which did not, however, seem to possess any advantages over those made with lead and manganese, and as they were more costly they were not made on a commercial scale. It is desired, however, to call especial attention to the fact that cobalt and nickel driers have been made, and are efficient, because it is commonly said in books on the subject that lead and manganese are the only metals which can be used in this way. The writer also made a vanadium compound which was a highly efficient drier, but of course its cost prevented its use. The mistaken statement above referred to is to be found even in so excellent a work as that on Drying Oils by L. E. Andés (of Vienna), which can be highly recommended to those seeking detailed information in regard to this class of oils, including many not well known.

These cobalt and nickel driers were made by the author about 1895.

Linseed-oil is obtained from flaxseed, which is produced in many parts of the world. Formerly it was common as far south as Virginia and Missouri, and in all the states north of the latitude of these states; it may be raised anywhere that the ordinary cereals will grow; but for some reason it is now produced only in Minnesota and the states west. Flax is liable to attack by a fungus which gets into the soil and destroys the root of the plant; this fungus remains from one year to another, so that it is found desirable to sow the seed on land which has not been used, especially on which flax has not been the previous crop. This has tended to restrict its production to regions where wild land is coming under cultivation. But is is held by agricultural experts that proper selection of vigorous seed will overcome this disadvantage. Seed is also obtained in large amount in the country north of the region named. Russia has always produced much flaxseed, and oil made from seed grown in the Baltic provinces is highly regarded. India also grows flax, and Calcutta seed oil is preferred for some purposes by varnish-makers. In South America, Argentina exports a large quantity of seed.

Difference in Oil-seed.—The oil from seed from different localities varies. South American seed is clean, the grains are large and plump, but the percentage of oil is rather low and the oil is slow to dry and forms films which never get as hard as those made from Northern seed. Its iodine number is sometimes as low as 170 and has been reported considerably lower; while North American oil is 178–185 and sometimes 190. This is regarded as the best indication of hard-drying quality. Calcutta oil has a lower iodine number than North American, but higher than La Plata; it is remarkable for its resistance to acid, not showing much free fatty acid after acid-bleaching. The oil from the higher and mountainous parts of India has a higher iodine number than that grown near Bombay. For varnish-making Calcutta oil is believed to discolor less on prolonged heating than other oil; and extreme hardness of drying is not thought to be so important in the oil because the addition of resin is depended on to harden the film. But in paints this is not so; a hard-drying film is desirable; and much trouble is due to La Plata oil. It is maintained by some that this softness can be remedied by the addition of a portion of cooked tung oil.

Oil-pressing and Oil-cake.—A gallon (231 cu. in.) of linseed oil weighs 7.78 lbs., but oil is sold at wholesale by the conventional gallon of 7.5 lbs. A bushel of flaxseed weighs 56 lbs.; North American seed contains 36.5 to 40 per cent of oil and in practice yields about 32 to 33 per cent., the remainder, 4 to 8 per cent., remaining in the oil-cake. Thus a bushel of seed produces about 2½ gallons of oil and 37 lbs. of cake. This is American practice. In Europe the cake is allowed to contain 20 per cent. of oil; this adds to its feeding value; and this will allow only 22 or 23 per cent. of oil to be extracted from the seed. According to this practice the oil-mills are run primarily to produce oil-cake, and the oil is a by-product; whereas in America, with oil at say 50 cents per gallon and cake $20 per ton, a bushel of seed produces $1.25 of oil and $.37 of cake. American oil-cake is sold in Europe at a low price as compared with European cake. In Europe a bushel of seed produces 1¾ (American) gallons of oil and 43 lbs. of high-priced oil-cake.

It should be said that oil-cake is often much higher than \$20 and oil is occasionally worth 80 cents per gallon. Our oil-cake contains from 4 to 7 per cent. of oil, seldom over 6 per cent.; and about 36 per cent. of protein, five-sixths of which is digestible; with 40 to 50 per cent. of carbohydrates. It is largely exported, and the foreign demand affects the price of our seed; but our oil is used at home.

Oil-bleaching.—The most common method of bleaching oil is with about 1 per cent. of 66° Bé. sulphuric acid, which is added slowly with agitation to the cold oil. After agitation for a sufficient time it is allowed to settle overnight, the clear oil decanted off, agitated with water and finally with a jet of steam; after settling this washing is repeated. Such oil contains a little free fatty acid, which does not seem to injure it for any purpose. A more thorough bleaching is done as follows: Starting with the oil at 60° F., add with agitation 3½ per cent. of its weight of a 15° Bé. solution of caustic soda, and agitate thirty minutes or longer; then heat it to 100° F., and cool (by cold-water pipes in the tank) to 70° F., and let it settle. Decant, or siphon off; filter the last portion; to the clear oil add 7 or 8 per cent. of its weight of fuller's earth with thorough agitation, raising the temperature to 150° F. or 180° F., and with half an hour's agitation at this temperature the bleaching will be effected. It is then filtered. This makes a very pale oil, and if afterward sun-bleached it is the palest linseed oil obtainable. Sun-bleaching, however, makes little or no difference in the color of varnishes made from it, as on heating it makes products of the same color as if the sun-bleaching had been omitted. This fuller's earth bleached oil is the finest and palest varnish-oil or artist's oil. Other vegetable oils may be bleached in the same way.

Referring back to the sulphuric-acid bleaching, it should be said that the amount of acid varies according to the results desired. Instead of using 1 per cent. of strong acid, 1 per cent. of a weak acid containing only 15 per cent. of the H_2SO_4 is sometimes used; the subsequent treatment being the same.

Bleaching with Chlorine.—An elaborate method for chlorine-bleaching was published a few years ago by the German government for the advantage of those who buy amber (which is a German government monopoly) for varnish-making. According to this, the bleaching solution was made by dissolving 12½ lbs. of bichromate of potash or soda in 60 lbs. of water; this is heated to boiling in an iron pot, and 3¾ lbs. of powdered MnO_2 is added; while hot add 30 lbs. chlorhydric acid, and as soon as chlorine fumes begin to come off add this slowly with vigorous agitation to 1000 lbs. linseed oil, previously heated to 100° F., which is contained in a wooden tank provided with wooden faucets. Agitate half an hour or more, then let it settle five days in summer or ten in winter; draw off the clear oil, let it stand in a clean tank two weeks in summer or four in winter, again draw off and it is ready for use.

This appears to be a fairly good bleach, but not better than the methods already described, and much more difficult and costly.

Stand-oil, Lithographic Oil.—Certain oil manufacturers in Holland have long been noted for a prepared oil which they call "stand-oil" and which has also been made in large quantity but of somewhat inferior quality in other parts of Europe. This corresponds approximately to what in this country is called lithographic oil, and which is made from a refined linseed oil by heating it at a rather high temperature for a considerable time. This is done in this country in copper kettles over a direct fire, and the heat is rather higher than 600° F. In Europe the kettles are enamelled, or silvered, or of aluminum; and it is not unlikely they may be heated in a bath of melted lead, or by superheated steam in a steam-jacketed kettle. From the writer's experience he has no doubt that contact with either copper or iron should be avoided. Oil heated to 630° or 640° F. rapidly thickens. No dryers are allowed to be in this oil, which is as viscid as thick molasses, and the best is hardly more colored than ordinary raw oil. Some of the best had a green tinge. Such oil may be thinned with turpentine or benzine, dryers may be added to it if desired, and it dries with a good and permanent gloss, forming a hard film, less elastic and probably less durable than ordinary oil. It is used in making printing inks, and is mixed with prepared tung oil as an ingredient of paints and varnishes. The writer has recently used an electrically heated kettle, which with some modifications appears to be well adapted to making such preparations.

Blown Oil.—Oil is also thickened by oxidizing it with a current of air blown through it. This has long been known, and oil slightly thickened by air-blowing has been sold as artificially aged oil for many years. If cold air is blown through cold oil, nothing happens; at least not for a long time; even the iodine number changes very little, but if the oil or the air is heated, oxidation begins at once. In ordinary practice the oil is heated to 300° or 250° F. and a large volume of cold air is blown through; the air escapes through small perforations, about ⅛ inch in diameter, from a submerged pipe. The temperature after a certain stage is reached tends to increase from the natural process of oxidation, and it is necessary to cool the oil, either by stopping the operation or by running cold water through the steam-jacket. The temperature should be held at 370° to 400° F. After a few hours the oil begins to foam badly; the foam may be beaten down with a varnish-maker's whip, or if a supply of hot air is at hand, a jet of hot air directed from above on the foam will break it down.

Air may be heated to 400° F. in a super-heater, simply a coil of pipe in a furnace, and the oil may be blown with this without otherwise heating the oil. This differs somewhat from oil blown with cold air; it dries better, the color is a little paler, but it is more liable to completely polymerize into a jelly than if made with cold air. When the oil is foaming the temperature should be kept below 290° F., but when the foaming ceases the heat may go up to 400° F. If the operation is not continuous, after the oil gets thick it will be so thick in the morning, after cooling through the night, that it must be heated to make it fluid enough so that the air will bubble through it; hence it is necessary to have a steam-jacketed bottom; and this can be utilized also for cooling, as before noted. To oxidize 600 gallons of oil requires air from a rotary pump with a 3-in. outlet running 225 r.p.m. for about forty to fifty hours. This will oxidize it as much as possible without letting it solidify; if it jellies nothing can be done with it except to make it into soap; but when stopped a little short of that it may be thinned while hot (225° F.) with turpentine or benzine, using about as much as there was of the oil; this will reduce it to about the viscosity of varnish. Or the thick oil may be stored in an open tank for use; it will not run out of a cock when cold and must be dipped out. About 10 per cent. more oil by weight is produced than was originally weighed in, besides unavoidable loss. The vapor and spray are pungent and offensive, and provision must be made for drawing off and disposing of them. This heavy blown oil not only dries by itself, but it responds to dryers; and as its viscosity is very high it can be used in making rosin varnishes; rosin is itself so nearly a liquid that the old type of rosin varnishes contained but little oil, but with this the more oil is used the higher the viscosity is, and rosin varnishes may be made with it which have considerable durability. The addition of prepared tung oil makes them also hard and glossy. It can also be used to cheapen ordinary varnishes, and is perhaps as little deleterious as anything that can be used for the purpose.

Boiled Oil.—What is commonly called boiled linseed oil is something different from blown oil or lithographic or stand-oil. It is ordinary raw oil, well settled and filtered, which has been heated with driers, such as the oxides of lead and manganese, and has taken a little of such substances into solution. There is a great variety of these products, but the name was originally given to oil which had been heated in an iron kettle over a direct fire, and about 1 per cent. each of litharge, red lead and manganese dioxide stirred in, and heated at 450° to 500° F. for from four to six hours with constant stirring. The manganese dioxide was not powdered, but about as coarse as grains of wheat. Not all the lead oxides were absorbed, and most of the manganese was left. The oil dries with a pronounced gloss and makes a film fairly hard overnight. This quality of forming a glossy film indicates high heat treatment. Operators differ as to the amount of lead and manganese; some oils which contain only lead, and some which contain only manganese have attained a good repute. The present practice is to dissolve, usually by heat, a certain amount of lead oxide and of finely powdered or precipitated manganese oxide in several (five to ten or more) times as much oil as is required to combine chemically with these; and this forms a " crushers' dryer " of which enough is added to a steam-heated tank of oil to give it a fifth of 1 per cent. of lead protoxide and a twentieth of 1 per cent. of oxide of manganese.

In general the oil dried with lead oxides is tougher but softer than with manganese, the latter making a harder film and drying with more " snap " and promptness.

Varnishes usually contain about ten times as much lead as manganese, and so do many of the paint dryers which are sold at retail. Various brands of boiled oil differ according to composition, temperature and time of cooking, and whether air-blowing is part of the process or not. There is a chance for an infinite variety; the one definite quality is drying within twenty-four hours. Boiled oil is now on the market containing cobalt, but no lead or manganese.

More will be said in the chapter on driers which has a bearing on this subject.

CHAPTER V.

LINSEED-OIL.

By Dr. Parker C. McIlhiney.

Linseed-oil is the oil obtained from the seeds of the flax-plant, *Linum usitatissimum*. Formerly the oil used in the United States was obtained principally from Indian and other foreign seed, but of late years the domestic seed has gradually replaced the foreign, although considerable quantities of Calcutta seed are still imported. The oil obtained from Calcutta seed usually commands a higher price, as it is of a light color, and is by some considered superior to that obtained from American seed. Any real superiority of Calcutta oil is, however, difficult to define, and it is likely that prejudice in favor of the imported article has much to do with the preference. Calcutta oil is generally sold raw and is largely consumed by varnish-makers.

Linseed is a crop which has a very exhausting effect upon the soil, and it is for this reason grown in the United States mostly on the frontier of the agricultural territory. The result of this is that the principal sources of supply for domestic seed are gradually moving farther west and northwest. It is estimated that 13,000,000 to 14,000,000 bushels of flaxseed were grown in the United States in 1898, and that the production in 1899 will reach 15,000,000 bushels. The usual yield of oil is in the neighborhood of 2.3 gallons per bushel of seed.

The methods of extracting the oil are two, by extraction with volatile solvents and by pressing. The extraction method is not, to my knowledge, practised in New York State. To extract the oil by pressing, the seed when it arrives at the mill is first cleaned, then ground to meal in high-speed rolls, and heated by steam. In some mills the heating is done by steam injected directly into the meal as it runs in a stream into a tub used as a reservoir of hot meal. In other works the heating-tub is steam-jacketed and no free steam is admitted to the meal. From the heating-pan the meal is delivered to a machine which fills it into canvas forms and presses these forms lightly to make them keep their shape sufficiently to handle. They are then placed in hydraulic presses and subjected to high pressure, causing the oil to run out. The oil at this stage contains various foreign matters, called collectively "foots," which have been pressed out with the oil. These are removed by settling, or by filtration through cloth and paper in filter-presses, or by both. The separation of "foots" on storage goes on for a long time; and the oil improves by storage and settling, even after careful filtration.

The operation of "boiling oil" is one about which great secrecy is observed by the manufacturers. When linseed-oil is heated to a temperature of 300° to 500° F., its drying properties are increased. If salts of lead or of manganese are incorporated into the oil a similar result is produced, and the simplest, and in former times the universal method of increasing the drying properties of linseed-oil, was to heat the oil to near the temperature at which it undergoes destructive distillation, 550° F., or thereabouts, and stir in at the same time oxide of lead, or oxide of manganese, or both. Heating th oil to such a high temperature darkens it very much, and as light-colored oil is often demanded, so that the oil will not discolor pigments suspended in it more than necessary, and as this high heat is wasteful of oil, time, and fuel, it has become the practice to make a "drier" of the metallic oxides by heating them with a small portion of the oil until they are dissolved, and then adding this drier to the main body of the oil maintained at a much lower temperature, usually not much above the boiling-point of water. The result of this process is that there is not so great a loss of oil during the boiling, and the oil obtained is lighter in color. The use of this method of making boiled by adding to raw oil, at a comparatively low temperature, a drier made by a separate operation, has induced the majority of makers of boiled oil to buy their driers from a varnish-manufacturer, who is better equipped, from the nature of his business, to make driers than the linseed-crusher is. The division of labor between the varnish-maker and the linseed-oil manufacturer results in enabling the linseed-crusher to dispense with all apparatus for heating oil to very high temperaturers, and is on this account advantageous to him. This same division of labor has, however, had the further effect of allowing the manufacturer of driers an opportunity to introduce into them, for his own profit, materials which the oil-manufacturer who is endeavoring to produce a pure article would not wish to add to his oil.

It is claimed by the makers of the so-called "bunghole" oil (a simple mixture of raw linseed-oil with drier), and also by the manufacturers of driers to be used in this way, that the oil made by this process is just as good as kettle-boiled oil, that no fraud is intended by the manufacturers of such oil, and that, in fact, it is simply a variety of boiled oil.

On the other hand it is claimed by the linseed-crushers and others who make boiled oil from linseed-oil and metallic oxides alone, that the only materials which it is necessary to add to a linseed-oil in converting it into boiled oil are the oxides of lead and manganese; that no one who can obtain the proper facilities for making boiled oil, viz., a kettle in which it can be heated and agitated, finds it necessary to use a drier thinned with benzine or turpentine, and that, in fact, these are in the finished oil simply dilutents detracting from the value of the oil; that it is not necessary to use in the manufacture of drier for making boiled oil any shellac, kauri-dust, rosin, or rosin-oil, or, in fact, anything but linseed-oil, lead, and manganese; and finally that the sale as "boiled oil" of oil which contains anything but linseed-oil, lead, and manganese is a fraud and should not be permitted.

The character of boiled linseed-oil, as it is described in the literature, even in the latest books, does not agree with that of the oil now made in this State. It is described in the literature as being made at a high temperature in the old-fashioned way, whereas little, if any, oil is now made in that way. There is a strong prejudice in the minds of most of the users of boiled oil in favor of the old-fashioned "kettle-boiled" oil. Consequently the manufacturers are somewhat averse to admitting that their oils are made after the modern fashion, although no advantages can be claimed for the old way. This prejudice in favor of strongly heated oil is so strong that the dark color of the old oil is imitated by many manufacturers by using dark-colored driers, although it is perfectly evident that for use with all light-colored pigments the lighter an oil is in color, other things being equal, the more desirable the oil is. This prejudice seems to be stronger in the East than in the Western States.

Section 1 of chapter 412 of the law relating to linseed- or flaxseed-oil prohibits the manufacture or sale as boiled linseed-oil of oil which has not been heated to 225° F. The intention of this provision is undoubtedly to prevent the manufacture of "bunghole" oil, but it is difficult to understand why an oil should be excluded if it is made from proper materials at a lower temperature, and still more difficult for an analyst to ascertain the temperature to which the oil has really been heated. No means are known to me by which it is possible to find out whether a sample of boiled linseed-oil has or has not been heated to 225° F.

The analytical investigation of linseed-oil and its adulterants was carried on with the idea, first, of ascertaining the character of pure linseed-oil sold in New York State by various manufacturers; secondly, to ascertain what the adulterants commonly used in the State are; and, thirdly, how prevalent the practice of adulteration is. With these ends in view, a series of samples was obtained, in most cases directly from the manufacturers, but partly also from large users of the oil, which are of undoubted commercial purity. Another series of samples was obtained by purchase from smaller dealers. Samples of oils likely to be used as adulterants were obtained from manufacturers or large dealers.

TESTS FOR PURITY OF OIL.

The tests which are valuable particularly in determining the freedom from adulteration are:

1. Specific gravity.
2. The action of bromine or iodine on the oil. Hübl and bromine figures.
3. The percentage of unsaponifiable organic matter.
4. The amount of alkali required to convert the oil into soap. Kœttstorfer figure.
5. The amount of alkali required to neutralize the free acids in the oil. Acid figure.
6. The percentage of insoluble bromine derivatives.
7. The amount of volatile oil (turpentine and benzine) contained in the oil.

Other tests often applied to linseed-oil are the Maumené test, which is the measurement of the temperature caused by mixing measured amounts of the oil and of sulphuric acid; the amount of oxygen absorbed by the oil when exposed to the air in thin films, called Livache's test; the index of refraction; and the action on polarized light.

1. **The Specific Gravity.**—Linseed-oil is heavier than most other oils. Its specific gravity is expressed in terms of water at 4° C. or 15°.5 C., or water may be taken as unity at whatever temperature the determination of specific gravity is made. It is advisable that some standard of temperatures should be set and adhered to in future determinations, as exactness and simplicity are above all else necessary in work that may be submitted as evidence in a court of law. It is at all events advisable that, even if the actual determination is made at a temperature different from the standard, it should be expressed in terms of water at the standard temperature. Unfortunately many of the recorded determinations do not state either the temperature at which the determination was made, or the temperature at which water is taken as unity. These determinations have consequently

little legal value. I should recommend, as the conditions which combine the greatest ease with the best accord with published data, that the gravity should be determined at 15°5. C., water at the same temperature being taken as unity. Almost all the determinations of specific gravity given in this report were made under these conditions.

The specific gravity of linseed-oil may be taken with the greatest accuracy by means of a specific-gravity bottle, the weight of which is determined empty, full of water at 15°.5 C., and filled with the oil to be examined at the same temperature. Another very convenient laboratory method having only slightly inferior accuracy, and the method by which almost all the determinations given in this report were obtained, is in application of the principle of Mohr's hydrostatic balance, by using a plummet with the ordinary analytical balance. For rougher work a delicate hydrometer may be used.

The specific gravity of raw linseed-oil is given by Allen's Comm. Org. Anal,, 3d ed., vol. 2, part 1, p. 147, as generally about .935, but varying from .931 to .937. The temperature is not stated, but it is presumably 15°.5 C. These limits are the same as those set in Benedikt, Analyse der Fette und Wachsarten, 3. Aufl., p. 429, and no oils of undoubted purity which I have examined have fallen outside of these limits. It may, therefore, be stated as an established fact that if an oil has a specific gravity at 15°.5 C., water at the same temperature being unity, that is below .931 or above .937, it is not pure raw linseed-oil.

The lower limit to the specific gravity of boiled linseed-oil may be set at the same point, .931, because a linseed-oil can only become heavier by heating with access of air and the addition of metallic oxides. Oils made with driers containing benzine may have lower specific gravities. The upper limit to the gravity it is difficult and indeed impossible to set, because genuine linseed-oil may be raised to .950 or higher by continued heating, though it is not commonly above .940.

Expansion by Heat.—The change in gravity, with change of temperature, of linseed-oil, and of some other oils, has been determined by Allen, Comm. Org. Anal., 3d ed., vol. 2, part 1, p. 33, and the following are some of his results:

Nature of Oil.	Correction for 1° C.
Linseed	.000649
Menhaden	.000654
Cottonseed	.000629
Rape	.000620

According to the results obtained by Saussure, the coefficient of expansion of linseed-oil is not uniform between 12° C. and 94° C. He records the following results (Benedikt, p. 428):

Temperature.	Specific Gravity.
12° C.	.939
25° C.	.930
50° C.	.921
94° C.	.881

Calculating from these results we obtain, as the variation for 1° C., between 12° C. and 25° C., .000692; between 25° C. and 50° C., .000360; and between 50° C. and 94° C., .000909. It will be seen from the table giving the results of determinations of specific gravity at different temperatures that I do not find in the oils examined a similar change in the rate of expansion. The averages of the figures obtained with raw oils, Nos. 52 and 73, and boiled oil, No. 72, show that the change in specific gravity for 1° C., between 15°.5 C. and 28° C., was .000654; between 28° C. and 100° C., .000720; and between 15°.5 C. and 100° C., .000712.

A low specific gravity in an oil under examination might be caused by the presence of (1) turpentine or benzine (indicated also by odor); (2) heavier petroleum-oils; (3) corn- or cottonseed-oils.

A high specific gravity would point to (1) rosin or other resin; (2) rosin-oil; (3) excessive heating or unusual addition of metallic oxides.

2. The Action of Bromine or Iodine on the Oil.—Linseed-oil is largely composed of constituents which are unsaturated, and which can, therefore, combine by direct addition with 2, 4, or 6 atoms of bromine or iodine. Of the adulterants of linseed-oil, mineral and rosin oils and rosin itself possess this power only to a slight degree, and none of the other adulterants except menhaden-oil possess it in as high a degree as linseed-oil. Besides the principal action of bromine or iodine upon linseed-oil, i.e., direct addition of halogen, another action takes place by which one half of the halogen which disappears enters into combination with the oil, and the other half combines with hydrogen which the first half has replaced in the oil.

The substitution of bromine or iodine for hydrogen goes on to only a slight extent with seed-oils and with glycerides in general, but with rosin, rosin-oil, and mineral oils, the case is very different. It has been proved by the author that when bromine acts upon rosin and upon rosin-oil, although a large amount of bromine is changed from the free into the combined state, almost all of the bromine is taken up by the rosin or oil by substitution, and not by addition, and in the case of ordinary American mineral oils, that taken up by substitution is a large proportion of the total absorption.

The process in most common use for determining the percentage of halogen absorbed by oils is known as the Hübl process; and though, by its use, valuable indications as to the purity and value of linseed-oil are obtained, it unfortunately does not distinguish between the power of the oil to absorb halogen by addition and the power it likewise possesses of absorbing halogen by substitution. The Hübl process, on this account, fails to discriminate closely between rosin, which is one of the likeliest constituents of a linseed-oil substitute, and linseed-oil itself, as the Hübl figures for the two substances are not very different.

A process described by the author (J. Amer. Chem. Soc., 16, 56), similar to one used previously by Allen for testing shale-oils, distinguishes between addition and substitution, and by its use the presence of any notable amount of rosin, rosin-oil, or mineral oil can be detected with a considerable degree of accuracy, and a fair idea formed of the character of the adulterant.

Hübl Process.—The Hübl process is one of the best-known methods of fat analysis; the method by which the Hübl figures were obtained for this report was as follows:

A solution of 25 grams of iodine and 30 grams of mercuric chloride in one liter of alcohol is allowed to stand, after making, for twenty-four hours in the dark before using. Two hundred milligrams or thereabout of the oil to be analyzed is weighed into a glass-stoppered bottle, 10 cc. of chloroform added to dissolve the oil, and 25 cc. of the iodine solution added. If the solution, when shaken to mix the chloroform and alcoholic liquid, does not become clear, 5 cc. more of chloroform is added. The bottle is then allowed to remain in the dark eighteen hours, and at the end of that time a solution of potassium iodide is added, and the free iodine in the solution titrated with tenth-normal sodium thiosulphate. Twenty-five cubic centimeters of the same iodine solution which has been placed in a similar bottle and allowed to stand with the test is titrated at the same time with thiosulphate, and the difference between the two titrations gives the amount of iodine absorbed by the oil. Full discussions of the process are given in Benedikt, Analyse der Fette und Wachsarten, and in Allen, Commercial Organic Analysis, Lewkowitsch, Oils, Fats, and Waxes, and Gill, Oil Analysis.

McIlhiney's Method with Bromine.—The bromine figures were obtained by a modification of the author's original method. The method actually used was as follows:

About 200 milligrams of the oil was placed in a dry glass-stoppered bottle, 10 cc. of carbon tetrachloride added to dissolve the oil, and then 20 cc. of third-normal bromine in carbon tetrachloride run in from a pipette. Another pipetteful is run into another similar bottle. It is convenient, but not absolutely necessary, that both bottles should now be cooled by immersing them in cracked ice. This causes the formation of a partial vacuum in the bottle. The bromine need not be allowed to react with the oil for more than a few minutes, as the reaction between them is nearly instantaneous. Twenty-five cubic centimeters of a neutral 10 per cent. solution of potassium iodide is introduced into each bottle by slipping a piece of rubber tubing of suitable size over the lip of the bottle, pouring the iodine solution into the well thus formed, and shifting the stopper slightly so as to allow the solution to be sucked into the bottle, or, if the bottle has not been cooled, to cause the air as it escapes from the interior to be washed by bubbling through the potassium iodide solution. This method of introducing the iodide solution effectually prevents the loss of any bromine or hydrobromic acid. As soon as the iodide solution has been introduced, the bottle is shaken, and preferably set into the ice for a couple of minutes more, so that there may be no loss of drops of the solution when the stopper is opened, caused by a slight pressure inside the bottle. The reaction between the bromine and the iodide solution causes some heat and consequent pressure. The free iodine is now titrated with neutral tenth-normal sodium thiosulphate, using as little starch as possible as indicator. At the end of this titration 5 cc. of a neutral 2 per cent. solution of potassium iodate and a little more starch solution are added and the iodine liberated, on account of the hydrobromic acid produced in the original reaction of bromine on the oil, titrated with thiosulphate. From the figures so obtained the total percentage of bromine which has disappeared is calculated, and the percentage of bromine found as hydrobromic acid, called the "Bromine Substitution Figure," is also calculated, while from these two the "Bromine Addition Figure" is obtained by subtracting twice the bromine substitution figure from the total bromine absorption. A consideration of the figures submitted in the table will show that if an oil contains rosin, rosin-oil, or mineral oil, the fact will be brought out by this process, and an indication given by the figures so obtained as to which one is present. If the bromine substitution figure is normal, the absence of more than a very small quantity of turpentine, benzine, rosin, or rosin-oil is assured. The process can be carried out in the time necessary for weighing and titrations, as the standard solution, unlike the Hübl solution, does not deteriorate on keeping, if tightly closed, so that it is always ready for immediate use, and there is no waiting for some hours for the reagents to act upon the oil, as in the Hübl process, for in this case the reaction takes place immediately.

It will be seen from the table of results that the Bromine Addition Figure of linseed-oil lies ordinarily between 100 and 110. The low figures of No. 1 and No. 2 are to be accounted for by the fact that the samples are several years old, and it is well known that keeping lowers the halogen figures of linseed-oil.

A low Addition Figure may also be caused by the presence of rosin, rosin-oil, benzine, or mineral oils, which have figures usually below 15; by the presence of some other seed-oil, the commonest of this class being corn- and cottonseed-oils, having figures in the neighborhood of 73 and 63 respectively; or by the oil, in case it is a boiled oil, having been boiled in the old-fashioned way at a high temperature.

If the Addition Figure is very much higher than 110, it will be found that the oil contains turpentine, as all other foreign materials added have lower figures than linseed-oil.

The Bromine Substitution Figure of genuine linseed-oil is commonly about 3. A much higher figure would point to turpentine, rosin, or rosin-oil, which give figures from 20 to 90; to the presence of some petroleum product, as benzine, having a figure in the neighborhood of 15, or a heavier petroleum-oil, which may have as low a figure as linseed, or may be much higher; or to the presence of mineral acid in the oil, which may be allowed for by a separate determination of its amount, as described under the determination of the Acid Figure.

The Hübl figure of raw linseed-oil is given by Benedikt from 148.8 to 183.4. Boiled oil, according to the same author, may give figures below 100. Allen gives the figures for raw oil between 170 and 181. Rowland Williams states that a very large number of raw linseed-oils examined by him almost all gave figures above 180. The figure is reduced by keeping. From the table of results obtained upon the oils examined it will be seen that the figure of pure oil is commonly in the neighborhood of 178

It is a noteworthy fact that both the Hübl and the Bromine Addition Figures are practically the same for boiled oil as now made as for raw oil, whereas boiled oil made by the old process at a high temperature gave distinctly lower figures on account of the effects of the high heat upon the oil.

In order to facilitate comparison between the Hübl and the bromine figures of the oils examined, the amount of bromine equivalent to the iodine absorbed as expressed by the Hübl figure has been calculated, and by dividing this result by the Bromine Addition Figure a figure was obtained for each oil which is intended to express, by the amount it exceeds 1.000, the amount of substitution of iodine which has gone on in the Hübl iodine absorption. For example, if the figure obtained for an oil by the calculation described is found to be 1.075, it indicates that the Hübl figure is in that case 7.5 per cent. higher than the true iodine figure which should express the iodine absorption by addition.

The Hübl figures of a number of the oils received last were not determined, because it did not appear that the determinations would add any information to that given more fully by the bromine figures.

It is not believed that the Bromine Addition Figure is sensibly affected by the length of time that the oil is allowed to remain in contact with bromine, but the Bromine Substitution Figure probably is. The effect of the difference between five minutes' and thirty minutes' contact does not appear, however, to be marked, unless the substitution figure is very high, as in the case of pure resin or turpentine. The results reported were obtained by about fifteen minutes contact.

In carrying out either the Hübl or the bromine process upon oils it is necessary that an excess of iodine or bromine should be used amounting to as much as the oil absorbs. Many iodine figures on record are too low because this precaution was not attended to.

It is believed that more information is to be obtained as to the character of a sample of linseed-oil by determining the bromine figures than by any other single test. In the case of an oil of unknown character it would in most cases be advisable to apply this test first to it.

3. The Percentage of Unsaponifiable Organic Matter.—Linseed-oil, being composed almost entirely of fatty matter of the ordinary type, compounds of fatty acids with glycerin, gives only a small percentage of material which cannot be saponified. The amount to be found in raw linseed-oil has been investigated by Thompson and Ballantyne (J. Soc. Chem. Ind., 1891, 10, 336), who find amounts varying from 1.09 to 1.28 per cent. in oil from various sources, and by Rowland Williams (J. Soc. Chem. Ind., 1898, 17, 305), who finds that it varies from 0.8 to 1.3 per cent. Williams, loc. cit., has also determined the amount of unsaponifiable matter in boiled oil, and finds that the amount is nearly twice as great as in raw oil, his figures for boiled oil being 1.3 to 2.3 per cent.; being usually about 2 per cent. Williams regards any oil with a percentage of unsaponifiable matter higher than 2.5 as adulterated. His statements refer to oil which has been boiled at a high temperature, and the boiled oils for sale in New York State are apparently all made at too low a temperature to cause any increase in the amount of unsaponifiable matter contained, with the exception of the oil in the drier. In view of these facts, 2.5 per cent. would be a reasonable limit to the amount of unsaponifiable matter in linseed-oil. This is so well established that it was not thought advisable to make this determination upon the pure oils examined.

It may be noted that in case an oil is found to contain unsaponifiable matter in excessive amount, the evidence which can be furnished the prosecution may be made of the most conclusive character, for the adulterant can be actually separated from the genuine linseed-oil and exhibited, whereas, in the case of some other adulterants, the evidence, though it may be conclusive, is of a character requiring more demonstration to one unfamiliar with the scientific examination of oils. The adulterants whose presence can in this way be demonstrated by actual separation are mineral oil and usually rosin-oil. Benzine and turpentine, although unsaponifiable, are not found with the unsaponifiable matter, as, from the nature of the methods of analysis, only materials that are practically non-volatile are counted as unsaponifiable. They are easily separated and determined, however, as volatile oil.

There are several methods for determining the percentage of unsaponifiable material, proposed by different experimenters. Some treat the oil with alcoholic or aqueous solution of potash or soda, evaporate off the alcohol or water, and treat the dried soap with petroleum ether or chloroform to dissolve the unsaponifiable portion. Other experimenters, after saponifying the soap with alcoholic solution of potash and evaporating off the alcohol, dissolve the resulting soap in water and agitate the solution with ether several times to remove from the soap solution the unsaponifiable matter which it holds in suspension.

A method which can with safety be recommended for determining unsaponifiable matter in linseed-oil is substantially that described in Allen, Comm. Org. Anal., 3d ed., vol. 2, part 1, p. 112. A quantity of oil varying from 1 to 10 grams, depending upon the amount of unsaponifiable matter present, is boiled for two hours, with frequent shaking, with excess of alcoholic solution of caustic potash, in a flask provided with a return condenser. The alcohol is then distilled off until only a small quantity remains. The soap is then dissolved in water, using 75 to 100 cc. for the purpose, transferred to a tapped separator, and 50 cc. of ether added. The liquids are then mixed by shaking and allowed to settle. The aqueous liquid is then drawn off, the ethereal layer washed with a few cubic centimeters of water to which a little caustic potash has been added, and poured into a tared flask. The soap solution is then returned to the separator and extracted with another 50 cc. of ether in the same way. The combined ethereal solutions are evaporated on the water-bath, and when the ether has been completely removed the flask now containing the unsaponifiable matter is weighed. If the percentage of unsaponifiable matter found is large, it may be advisable to repeat the process of saponification and extraction upon the unsaponifiable matter, in order to be quite certain that no unsaponifiable oil has escaped the action of the alkali.

Determination of Mineral Oil.—The mineral oil may be separated from the rosin-oil in the unsaponifiable material found in the saponification process by the method suggested by the author in the Jour. Amer. Chem. Soc., 16, 385.

Fifty cubic centimeters of nitric acid of 1.2 sp. gr. are heated to boiling in a flask of 700 cc. capacity. The source of heat is removed, and 5 grams of the oil to be analyzed added. The flask is then heated on the water-bath, with frequent shaking, for fifteen to twenty minutes, and about 400 cc. of cold water added. After the liquid has become entirely cold 50 cc. of petroleum ether are added and the flask is agitated. The oil which remains unacted upon dissolves in the ether, while the rosin remains in suspension. The liquid is poured into a tapped separator, leaving the lumps of solid rosin as far as possible behind in the flask. After settling, the aqueous liquid is drawn off and the ethereal layer poured into a tared flask. Another portion of petroleum ether is added to the rosin remaining in the flask, and allowed to act upon it for about ten minutes, when it is added to that in the tared flask. After distilling off the ether, the oil is weighed. Mineral oils lose about 10 per cent. in this way, and hence the weight of oil found must be divided by 0.9 in order to find the amount present in the sample analyzed.

Allen found mineral oils to lose 10 to 12 per cent. on treatment with nitric acid. (Pharm. Jour., 3d series, 11, 266.)

Rosin-oil, though principally composed of hydrocarbons, may contain some unchanged rosin which is saponifiable, and consequently, in case rosin-oil is present, the amount of unsaponifiable matter which it furnishes is less than the total amount of rosin-oil present. The proportion between that found and the amount present will vary according to the way in which the oil was manufactured, and its consequent contents in unchanged rosin. Ordinarily the amount of saponifiable matter found due to rosin-oil is likely to be about nine-tenths of that present.

The amount of unsaponifiable matter found in the other animal and vegetable oils used as linseed-oil adulterants is approximately the same as that found in linseed-oil itself; hence the process does not furnish any clue to corn-, cottonseed-, or menhaden-oils, if they are present.

Petroleum-oils may be used in adulterating linseed-oil, which are just on the border-line between volatile and practically non-volatile oils. Such oil as, for example, kerosene would partly distil off with the alcohol in removing it after saponification, while the rest of it would remain to be extracted with ether from the aqueous soap solution, and be weighed as unsaponifiable matter. It might easily happen in such a case that the proportion of the partly volatile oil which would be obtained by distillation with steam in the determination of volatile oil would be a different one from the proportion removed from the saponified oil in distilling off the alcohol in the determination of unsaponifiable matters, and that the sum of the "volatile oil" and of the "unsaponifiable matter" would be more or less than the true total amount of adulterant added. In such a case it would be advisable to use for the determination of unsaponifiable matter a portion of the residue from the determination of volatile oil.

4. **The Amount of Alkali Required to Convert the Oil into Soap. Kœttstorfer Figure.**—This determination serves in the analysis of linseed-oil as an indication of the presence or absence of unsaponifiable matter, whether volatile or not. Its indications are not as valuable for this purpose as an actual determination of the unsaponifiable matter itself, but they are more readily obtained. The determination is made by the well-known Kœttstorfer process. About 2.5 grams of the oil is weighed into a flask, 25 cc. of half-normal alcoholic solution of caustic potash added and the liquid boiled on the water-bath with a return condenser, with frequent shaking, for about two hours. The liquid in the flask is then titrated with half-normal hydrochloric acid, using phenolphthalein as indicator. Twenty-five cubic centimeters of the same alcoholic caustic potash is titrated at the same time, and the difference between the two titrations gives the alkali used in saponifying the oil, and when calculated

in milligrams of potassium hydroxide to a gram of oil it is called the "Kœttstorfer Figure."

The Kœttstorfer Figure of raw linseed-oil is given by Benedikt from 187.6 to 195.2, and by Allen from 187.4 to 195.2. Benedikt's figures for boiled oil are from 180 to 190, and Allen's figure, calculated from his "Saponification Equivalent," is 188. Benedikt's figures are on the authority of Filsinger, Chem. Zeit., 1894, 18, 1867, and evidently apply to old-fashioned, strongly heated boiled oil. Both the exposure to high heat and the introduction of manganese and lead soaps of linseed-oil in the drier tend to reduce the Kœttstorfer figure. Of the two, exposure to high heat for a long time, as in the old-fashioned boiling process, reduces it far more than the introduction of the small percentage of lead and manganese soaps as used in practice. The boiled oils now for sale in this State have, as will be seen from the table, almost as high figures as the raw oils. It may fairly be demanded of a raw oil that its figure shall not be lower than 187, and of a boiled oil not lower than 186.

A low figure indicates the presence of mineral oil, having a figure below 10; of rosin-oil, having a figure below 20; or of benzine or turpentine, of both of which the figures are practically 0.0. Pure hydrocarbons give a Kœttstorfer figure of 0.0, but mineral oils usually contain traces either of mineral acid from the refining process, or of organic acids from oxidation by the air, and rosin-oils contain some unchanged rosin, which accounts for the Kœttstorfer figures.

5. The Amount of Alkali Required to Neutralize the Free Acids in the Oil. Acid Figure.—Perfectly pure linseed-oil contains only a very small percentage of free acids, while rosin is composed principally of free acids, and rosin-oil usually contains a notable proportion of free rosin. Therefore, the free acids in an oil which contains rosin will neutralize a larger proportion of alkali than those in pure linseed-oil. On keeping, the amount of free acid is likely to increase somewhat. The free acid found may be partly due to mineral acid used in refining the oil. The amount of mineral acid may be separately determined by boiling for some time a weighed portion of the oil with water, cooling the mixture, adding neutral potassium iodide and iodate, and titrating the liberated iodine in the aqueous solution with standard sodium thiosulphate. After deducting from the total percentage of potash required to neutralize the total free acid the percentage required for the mineral acid, the percentage required by the free organic acid is found, which, in the case of linseed-oil, are almost certain to be either the normal fatty acids from the linseed-oils or a combination of these with rosin acids.

The method of determining free acids is to weigh 5 to 10 grams of the oil in a flask, add about 50 cc. of alcohol, which is neutral to phenolphthalein, heat on the water-bath till the alcohol boils, shake well, and titrate with half-normal alkali. The results of the titration are expressed in milligrams of potassium hydroxide required per gram of oil, and the result is called the "Acid Figure."

Benedikt gives as the limits observed by Nördlinger, in examining ten samples of linseed-oil, acidities from .41 to 4.19 per cent. of oleic acid, corresponding to acid figures from .9 to 8.3. Mills allows a maximum figure of 10.0. As will be seen from the figures contained in the table, raw linseed-oil will usually give an acid figure in the neighborhood of 3.0. The figure of oil No. 1, though pure, is 7.1, due, no doubt, to the fact that it is several years old. The figures of boiled oil are slightly higher, due probably to the production of a small quantity of some acid body by the action of heat on the oil. The figure of boiled oil will usually be below 5, but is more uncertain than that of raw oil. A figure higher than 10.0 will almost certainly be found due to the presence of rosin. The acid figure of rosin is variously given by Benedikt, Williams, and Schmidt & Erban, from 145.5 to 179.2. Samples examined by the author (Jour. Amer. Chem. Soc., 16, 275) gave figures from 155.7 to 168.5. Fortunately rosin is also indicated by a high Bromine Substitution Figure and a low Bromine Addition Figure, and if all three point to rosin, it is probably there, but the safest course is the actual isolation of the rosin by Twitchell's or Gladding's process.

6. The Percentage of Insoluble Bromine Derivatives.—This determination is proposed by Hehner and Mitchell (Analyst, Dec., 1898, vol. 23, p. 310). It depends upon the fact that linseed-oil gives, when dissolved in ether and treated with bromine, compounds of glycerides and bromine which are insoluble in the ether, while oil containing glycerides of oleic acid only, and even semi-drying oils like cottonseed- and corn-oils, give soluble compounds. Hehner and Mitchell obtain the following percentages of insoluble bromine compounds from different oils:

Oil.	Per Cent. of Insoluble Bromine Compounds.
Linseed-oil	23.86 to 25.8
Poppy-oil	0.0
Corn-oil	0.0
Cottonseed-oil	0.0
Olive-oil	0.0
Almond-oil	0.0
Rapeseed-oil	0.0
Whale-oil	25.0
Cod-oil	35.5
Cod-liver oil	42.9
Shark-oil	22.0

The process, which seems to be a valuable one in detecting adulterations of linseed-oil with other seed-oils, was not published until late in the progress of this investigation, and it was impossible to carry on all the experiments with it that it deserves. It has seemed inadvisable, therefore, to present in full the results obtained. Two samples of raw linseed-, six samples of boiled linseed-, two of corn-, and one of cottonseed-oil gave results agreeing substantially with those of Hehner and Mitchell. Two samples of mineral oil, one light and one heavy, one sample of rosin-oil, and one sample of turpentine failed to give any precipitate of insoluble bromine derivatives.

7. The Percentage of Volatile Oil.—The presence of even a small percentage of turpentine in linseed-oil is distinctly indicated by the odor of the oil when placed in a vessel which it about half fills, the vessel closed, and heated in boiling water for a few minutes. The smell of turpentine will then be noticed on opening the vessel. Benzine is indicated, though not quite so distinctly, in the same way.

To determine the amount present, a convenient quantity, say 300 grams, is heated by means of a paraffin- or air-bath to about 130° C., in a flask provided with an outlet-tube for vapors, an inlet-tube reaching nearly to the bottom of the vessel, and a thermometer inserted into the oil. When the oil has reached the desired temperature a current of dry steam is passed through the oil and the vapors condensed in a Liebig condenser. The distillate will separate into a lower layer of water and an upper layer of volatile oil, which is separated and measured or weighed. The aqueous part of the distillate will inevitably carry with it a small quantity of volatile oil, but the quantity is very small. The amount of turpentine either dissolved or permanently held in suspension by water was found in one experiment made by the author (Jour. Amer. Chem. Soc., 16, 273) to amount to 0.300 gram in 90 cc. of water.

A separation of the benzine and turpentine in the volatile oil found is best effected by the method of Burton (Amer. Chem. J., 12, 102), which depends upon the difference between the action of fuming nitric acid upon benzine and upon turpentine, the former remaining practically unattacked, while the latter is strongly acted upon and converted into bodies soluble in hot water. The method may be described as follows: A measured quantity of the mixture to be separated is allowed to drop slowly into 300 c.c of fuming nitric acid contained in a flask of 750 cc. capacity, provided with a return condenser and immersed in cold water. A violent reaction takes place as each drop of oil strikes the acid, and the flask should be shaken occasionally. When all the oil has been added the flask is allowed to stand till all action is over. The contents of the flask are then poured into a separating-funnel and treated with successive portions of hot water; the products of the action of the acid on the turpentine are in this way removed, leaving the petroleum oil to be separated and measured.

The Maumené Test.—When oils are mixed with concentrated sulphuric acid the mixture becomes hot, and the rise of temperature varies with the nature of the oil. The chemistry of the process is but slightly understood. Non-drying oils do not give as great a rise as drying oils, and consequently linseed-oil gives a greater rise than any of its adulterants, except, unfortunately, menhaden-oil. The behavior with sulphuric acid is similar to the behavior with bromine and iodine, so that no more information is gained from the rise in temperature than is obtained by determining the percentage of halogen absorbed, except in the case of adulteration with menhaden-oil.

The test which is known as Maumené's test and which is fully described in Benedikt, Analyse der Fette, and in Allen, Comm. Org. Anal., vol. 2, is carried out by mixing 50 cc. of the oil to be examined with 10 cc. of strong sulphuric acid. The reaction with linseed-oil and with some other oils is so violent that the oil must be diluted with some more inert oil, or the mixture will froth over. The rise in temperature is observed by a thermometer used to stir the mixture, and the vessel in which the experiment is carried on is protected from rapid cooling by setting it inside another larger vessel, usually with cotton wool between. The amount ol heat abstracted by the vessel itself depends upon its mass and material, and the amount of loss by radiation is dependent upon a variety of circumstances. Consequently the results obtained by different observers with different apparatus have varied with the same oil, and each apparatus must be standardized by the observer by testing with a number of oils of known purity, or else by adopting the suggestion of Thomson and Ballantyne (J. Soc. Chem. Ind., 1891, 10, 233), and expressing the results in terms of rise of temperature produced by substituting an equal volume of water for oil, the results obtained with water being taken as 100. As stated above, the Maumené figure is usually higher the higher the halogen absorption. In the case of menhaden-oil, however, and perhaps other fish-oils, the Maumené figure is higher than would correspond with its iodine or bromine absorption. A sample having a bromine addition figure of 95, as against linseed-oil, which would have a figure usually about 102, would give a Maumené figure higher than that of the linseed-oil. Thomson and Ballantyne find that the specific rise of temperature of four samples of linseed-oil which they examined varied from 270 to 349, while the corresponding figure for a sample of menhaden-oil was 306. Allen found the rise of temperature with sulphuric acid to be 104 to 111 in the case of linseed-oil, and 126 in the case of menhaden-oil.

It will be seen from these facts that if an oil is found to give a distinctly lower bromine addition figure, and at the same time a Maumené figure distinctly higher than specimens of pure linseed-oil tested in the same apparatus, very strong evidence of the presence of fish-oil is at hand. It is advisable before testing a sample of oil in this way to remove from the oil all impurities, as far as possible. Volatile oil is removed with comparative ease. Free rosin can be largely removed by repeated treatment with moderately strong alcohol, and subsequent removal of any alcohol that may remain dissolved in the oil by treatment with water and settling, keeping the vessel hot. Unsaponifiable matter and soaps cannot be easily removed, but in extremely important cases it might be advisable to prepare a quantity of the fatty acids of the sample to be examined by saponifying and then acidifying the oil, after freeing it from rosin, as far as possible. Volatile oil could be removed during the saponification. This sample of fatty acids could then be tested under the same conditions as the fatty acids prepared from samples of pure linseed-oil.

Livache's Test.—The power possessed by linseed-oil in greater measure than by any other oil to absorb oxygen from the air, and consequently to increase in weight, is measured by Livache's test (Compt. rend., 1895, 120, 842). In order to hasten the absorption of oxygen a weighed quantity of the oil is spread out in a thin film on a watch-glass, and mixed with finely divided precipitated metallic lead. At the end of each period of twelve or twenty-four hours the mixture is weighed and the increase in weight noted. The amount of oxygen absorbed in this way by oils is roughly proportional to the absorption of bromine and iodine, except in the case of fish-oils. Menhaden-oil, though having a power to absorb bromine or iodine but slightly inferior to that of linseed-oil, falls very short in practical drying properties, and as Livache's test comes nearer than any other to an actual determination of the real drying power of an oil, menhaden-oil is indicated by a proportionately lower absorption of oxygen than of that of linseed-oil, than the bromine or iodine figures of the sample. Details of the process will be found in Benedikt, Allen, and Gill.

Livache found linseed-oil to gain 14.3 per cent of its weight in two days, while Jean (Monit. Scient., 15, 891) found menhaden-oil to gain only 5.454 per cent. in three days.

Thus if an oil have a bromine addition figure (after allowing for the effect of other impurities found) that is only slightly lower than that of linseed-oil, but absorbs only a small amount of oxygen by Livache's test, there is good proof of the presence of menhaden-oil.

With regard to other adulterants of linseed-oil the test does not furnish information at all comparable in value with that obtained by determining the bromine figures.

Index of Refraction.—With regard to the index of refraction the difference between the figures of linseed-oil and of its adulterants is comparatively small, and much less work has been done in this direction than in others. The following figures are taken from several authorities:

Oil.	Refractive Index.
Linseed-oil	1.484 to 1.488 at 15° C.
Cottonseed-oil	1.475 at 15° C.
Rosin-oil	1.535 to 1.549 at 18° C.
Mineral oil	1.438 to 1.507
Turpentine-oil	1.464 to 1.474
Rosin (colophony)	1.548
Corn-oil	1.478 at 20° C. 1.4765 at 15° C.
Fish-oil	1.480 at 15° C.

The Action on Polarized Light.—The use of the polariscope is very limited in testing linseed-oil. Little has been done with it, and its value in this connection seems to be confined to the detection of rosin-oil, which is dextro-rotatory. Valenta finds its rotatory power to be 30°–40°, and Demski and Morawski find it to be 50°. American oil of turpentine deviates polarized light to the right, while the French oil of turpentine deviates to the left. Mineral oils have no rotatory power, or only a slight one, and, according to Bishop, vegetable oils, with the exception of sesame-oil, rotate to the left. Therefore a right-handed rotation in a sample of linseed-oil is indicative of rosin-oil.

The Best Tests to Apply in Analyzing Linseed-oils.—In examining linseed-oil for adulteration it will usually be found advisable to make the following determinations:

1. Determine the specific gravity at 15°.5 C., water at the same temperature being taken as 1.000. This should be between .931 and .937 for raw oil, and between .931 and .950 for boiled oil.

2. Determine the bromine addition figure and the bromine substitution figure. The former should be between 100 and 110 and the latter should not be higher than 5, though it may rarely, in a pure oil, be as high as 7, probably from the presence of an unusual amount of non-fatty matter extracted with the oil from the seed. The figures to be expected are the same for raw oil and boiled oil as now made.

3. Test for volatile oil by the odor and determine the amount present by distillation with steam. There should be none.

4. Determine the amount of non-volatile unsaponifiable material. There should be less than 2.5 per cent. in either raw or boiled oil.

5. Determine the acid figure. It should be less than 5 in either raw or boiled oil, but figures as high as 7 may indicate that the oil is old rather than adulterated, and a still higher figure may prove to be due to the presence of mineral acid from refining.

6. Determine the Kœttstorfer figure. This should not be less than 187 in the case of raw oil, nor less than 186 in the case of boiled oil, and in neither case should be higher than 196.

7. If the appearance, odor, etc., of an oil point to the presence of fish-oil, apply Maumené's and Livache's tests.

Adulteration will usually be indicated by more than one test, and if abnormal figures are obtained by one process pointing to a certain kind of adulteration, while others, which would also be expected to be abnormal, are not so, it is evident that some new adulterant is to be sought for, or that the oil has, perhaps, been made by some unusual process.

Detection and Determination of the Several Adulterants.—1. *Non-volatile Mineral Oil.*—Indicated by low bromine absorption, low bromine addition figure, low Kœttstorfer figure, and low specific gravity. Separated and weighed together with rosin-oil as unsaponifiable matter, and separated from rosin-oil by nitric acid.

2. *Benzine.*—Indicated by odor, low specific gravity, low Kœttstorfer and bromine addition figures, and low bromine absorption. Separated and weighed or measured together with turpentine, as volatile oil, by distillation with steam, and separated from turpentine with fuming nitric acid.

3. *Turpentine.*—Indicated by odor, low specific gravity, low Kœttstorfer figure, and high bromine absorption, bromine addition figure, and bromine substitution figure. Separated and weighed together with benzine as volatile oil by distillation with steam, and determined by difference, after treating the volatile oil with fuming nitric acid and hot water.

4. *Rosin-oil.* — Indicated by high specific gravity, low Kœttstorfer figure, often high acid figure, low bromine absorption and bromine addition figure, and high bromine substitution figure. Separated and weighed together with non-volatile mineral oil as unsaponifiable matter, and determined by difference, after treating the mixture with nitric acid.

5. *Rosin.*—Indicated by high specific gravity, high bromine absorption, low bromine addition figure, high bromine substitution figure, and when in the free state by high acid figure. Separated and weighed or titrated by Twitchell's process (J. Soc. Chem. Ind., 1891, 10, 804). It is carried out by treating the mixed fatty and

rosin acids obtained by acidifying the soap solution after extraction with ether in the determination of unsaponifiable matter, in absolute alcohol solution, with hydrochloric gas. By this treatment the fatty acids are converted into ethyl esters, while the rosin acids are not. The products of the reaction are boiled with water, the mixed fatty acid esters and rosin separated and dissolved in naphtha. From this solution the rosin is extracted by potassium hydrate solution. The rosin soap solution is treated with acid and the liberated rosin weighed. For full details Allen's Comm. Org. Anal. (3d ed.) should be consulted.

Gladding's method, Amer. Chem. J., 3, 416, formerly much used for the determination of rosin, depends upon the solubility of silver resinate in ether, while the silver salts of fatty acids are insoluble.

6. *Menhaden-oil.*—Indicated by a bromine addition figure slightly lower than that of linseed-oil, but a higher Maumené figure and a very much lower figure by Livache's test. Indicated also by characteristic taste and odor.

7. *Corn- and Cottonseed-oils.*—Indicated by low specific gravity, low bromine absorption, and low bromine addition figure.

TABLE SHOWING THE EFFECTS OF TEMPERATURE UPON THE SPECIFIC GRAVITY OF LINSEED-OIL.

(In all cases water at 15.5° C. taken as unity.)

Oil.	Sample Number.	Specific Gravity 15°.5 C.	Specific Gravity 28° C.	Specific Gravity 100° C.	Change for 1° C., 15°.5–28° C.	Change for 1° C., 28°–100° C.	Change for 1° C., 15°.5–100° C.
American raw linseed. . .	52	.9336	.9255	.8736	.000650	.000721	.000711
Raw Calcutta linseed . . .	90	.9328	.9239	. . . . . .	.000698		
Raw American linseed. . .	92	.9336	.9255	. . . . . .	.000650		
Raw American linseed. . .	95	.9345	.9263	. . . . . .	.000656		
Boiled American linseed.	38	.9385	.9297	. . . . . .	.000707		
Boiled American linseed.	94	.9375	.9293	. . . . . .	.000653		
Raw American linseed . .	58	.9327	. . . . . .	.8732	. . . .	. . . .	.000704
Raw American linseed . .	73	.9332	.9245	.8731	.000693	.000714	.000711
Boiled American linseed.	72	.9336	.9258	.8735	.000625	.000726	.000714
Menhaden.	71	.9316	.9235	.8712	.000646	. . . .	.000716

A Table showing the Correction for Temperature to be Added to or Subtracted from the Readings of a Glass Hydrometer, correct at 60° F. (15°.5 C.), Immersed in Linseed-oil, for each Degree from 40° F. to 85° F.

Calculated from the results obtained in determining the specific gravity of samples Nos. 88, 90, 92, 94, and 95, by the following formula:

Let a = weight of oil displaced by glass plummet at 15°.5 C.;
b = weight of oil displaced by glass plummet at 28°.0 C.;
c = weight of water displaced by glass plummet at 15°.5 C.;
d = difference in apparent gravity of hydrometer for 1°.

$$\frac{\frac{a-b}{c}}{28-15.5}=d.$$

By substituting 82°.4 F. and 60° F. for 28° C. in the formula the correction will be found for 1° F.

Correction for 1° F. = .000361. Correction for 1° C. = .000650.

Thermometer Reading.	Subtract.	Thermometer Reading.	Subtract.	Thermometer Reading.	Add.	Thermometer Reading.	Add.
40 Fahr.	.0072	51 Fahr.	.0032	61 Fahr.	.0004	74 Fahr.	.0051
41 "	.0069	52 "	.0029	62 "	.0007	75 "	.0054
42 "	.0065	53 "	.0025	63 "	.0011	76 "	.0058
43 "	.0061	54 "	.0022	64 "	.0014	77 "	.0061
44 "	.0058	55 "	.0018	65 "	.0018	78 "	.0065
45 "	.0054	56 "	.0014	66 "	.0022	79 "	.0069
46 "	.0051	57 "	.0011	67 "	.0025	80 "	.0072
47 "	.0047	58 "	.0007	68 "	.0029	81 "	.0076
48 "	.0043	59 "	.0004	69 "	.0032	82 "	.0079
49 "	.0040	60 "	.0000	70 "	.0036	83 "	.0083
50 "	.0036			71 "	.0040	84 "	.0087
				72 "	.0043	85 "	.0090
				73 "	.0047		

TABLE OF THE RESULTS OBTAINED UPON THE OILS EXAMINED.

RAW LINSEED-OILS KNOWN TO BE PURE.

Number.	From Whom Obtained.	Specific Gravity at 15°.5 C.	Kœttstorfer Figure.	Acid Figure.	Hübl Figure.	Bromine Calculated from Hübl.	Per Cent. of Bromine Absorbed.	Bromine Addition Figure.	Bromine Substitution Figure.	Bromine from Hübl, Div. by Br. Add. Fig.	Per Cent. Unsaponifiable.	Per Cent. Volatile Oil.	Remarks.
1	A. H. Sabin...........	.9340	187.9	7.1	166.9	105.2	98.4	95.4	1.5	1.103	.....	.....	Sample several years old.
2	A. H. Sabin...........	.9322	190.7	.7	157.3	99.1	99.2	92.0	3.6	1.000	.....	.....	Old sample. Refined specially by Prof. A. H. Sabin.
52	John Carle & Sons.	.9336	192.4	2.6	184.2	116.1	116.1	109.6	3.4	1.059			
89	Dean Linseed-oil Co....	.9322	191.1	1.1	178.8	112.7	.....	.....	.....	.....	.....	.....	Unfiltered Calcutta oil.
90	Dean Linseed-oil Co....	.9326	191.1	1.0	178.6	112.6	108.5	102.1	3.2	1.102	.....	.....	Same as above, but filtered.
92	Dean Linseed-oil Co....	.9336	188.5	1.0	185.9	117.2	113.2	109.2	2.0	1.072	.....	.....	American oil.
95	National Lead Co.	.9345	190.0	1.4	186.3	117.0	112.2	106.5	2.9	1.098			
96	National Lead Co.	......	189.2	1.3	184.8	116.5	.....	.....	.....	.....	.....	.....	Same as previous oil, but unfiltered.
97	National Lead Co.	.9340	188.7	21.9	184.8	116.5	.....	.....	.....	.....	.....	.....	Refined with sulphuric acid.
140	Kellogs & Miller.	.9337	192.5	3.7	......	......	104.5	99.9	2.3				
151	Campbell & Thayer ...	.9340	192.0	1.3	......	......	115.1	109.5	2.8				
153	Cleveland Linseed-oil Co.	.9327	191.3	2.1	......	......	114.6	109.4	2.6	......	.83		
	Averages.	.9333	190.4	3.7	178.6	112.5	109.1	103.7	2.7	1.072			

RAW LINSEED-OILS, BELIEVED FROM ANALYSIS TO BE PURE.

61	F. J. H. Kracke	.9336	189.8	2.1	172.2	108.5	115.3	105.5	4.9	1.028		
63	F. J. H. Kracke	.9326	189.3	2.1	168.6	106.3	110.4	106.4	2.0	.999		
73	William McDonagh. ...	.9332	190.6	3.9	180.6	113.8	111.1	105.9	2.6	1.074		
82	Pool & Son..........	.9321	188.3	1.8	182.4	115.0	112.2	104.2	4.0	1.103		
83	J. H. Tieman..........	.9334	190.5	1.1	183.6	115.7	116.0	107.2	4.4	1.078		
84	Askin & Co..........	.9331	187.7	1.7	180.0	113.5	113.5	100.7	6.4	1.127		
86	T. J. Preston.	.9337	188.4	2.1	181.8	114.6	114.1	108.5	2.9	1.046		
91	C. A. Woolsey Paint Co..	.9324	192.0	2.4	174.5	110.0	109.0	105.2	1.9	1.045		
107	Nairn Linoleum Co. ...	.9335	191.7	1.7	......	......	107.3	100.9	3.2			
	Averages...........	.9330	189.8	2.1	177.9	112.1	112.1	104.9	3.5	1.062		

BOILED LINSEED-OILS KNOWN TO BE PURE.

88	Dean Linseed-oil Co....	.9385	191.1	4.2	180.4	113.7	106.0	100.8	2.6	1.126		
94	National Lead Co......	.9375	191.3	2.8	183.3	115.5	110.8	105.8	2.5	1.091		
141	Kellogs & Miller.	.9388	187.5	5.1	......	......	105.4	101.2	2.1			
152	Campbell & Thayer ...	.9474	192.1	5.7	......	......	110.0	103.2	3.4	......	1.12	
160	Hauenstein & Co.	.9383	192.2	5.3	......	......	109.8	105.2	2.3			
162	Mann Bros. & Co.	.9355	190.6	3.5	......	......	113.6	103.0	5.3			
163	Spencer Kellogg.	.9379	191.8	6.4	......	......	109.2	103.8	2.7			
165	A. B. Gibbs.	.9444	190.7	4.7	......	......	110.8	101.0	4.9			
	Averages...........	.9398	190.9	4.7	......	......	109.4	103.0	3.2			

TABLE OF THE RESULTS OBTAINED UPON THE OILS EXAMINED—(*Continued*).

BOILED LINSEED-OILS, BELIEVED FROM ANALYSIS TO BE PURE.

Number.	From Whom Obtained.	Specific Gravity at 15°.5 C.	Koettstorfer Figure.	Acid Figure.	Hübl Figure.	Bromine Calculated from Hübl.	Per Cent. of Bromine Absorbed.	Bromine Addition Figure.	Bromine Substitution Figure.	Bromine from Hübl Div. by Br. Add. Fig.	Per Cent. Unsaponifiable.	Per Cent. Volatile Oil.	Remarks.
101	Askin & Co.	.9363	191.5	4.1	178.0	112.2	110.3	103.5	3.4	1.084			
113	Charles Fleury	.9359	192.1	7.0	173.2	105.2	106.1	101.5	2.3	1.075			
114	E. G. Atwood.	.9362	190.2	3.4	176.6	111.3	106.0	101.4	2.3	1.097			
115	Abraham Bros.	.9367	193.8	3.1	179.7	113.3	111.6	108.0	1.8	1.030			
116	F. Schiller	.9359	189.2	3.3	182.9	115.3	111.9	104.7	3.6	1.012			
118	A. Levinsky.	.9368	192.6	3.5	175.0	110.3	112.8	106.4	3.2	1.036			
119	James Lawler.	.9394	194.6	5.2	174.4	109.9	110.4	103.4	3.5	1.062			
120	D. Lubelsky	.9366	193.7	3.9	177.6	111.3	111.4	105.2	3.1	1.057			
127	W. N. Nevius.	.9397	190.3	3.9	......	......	116.4	107.2	4.6				
139	John Geddes.	.9345	190.8	2.1	......	......	114.9	107.3	3.8				
	Averages.	.9368	191.9	4.0	177.2	111.6	111.2	104.9	3.2	1.057			
	BOILED LINSEED-OILS NOT MADE ENTIRELY FROM LINSEED-OIL, LEAD, AND MANGANESE.												
72	William McDonagh.	.9336	184.2	11.1	165.1	104.0	105.3	94.7	5.3	1.099	3.84		
85	J. H. Tieman.	.9350	182.2	8.4	168.5	106.2	112.0	92.6	9.7	1.147	6.89		
117	Samuel Sendacz	.9247	116.4	16.6	105.2	66.3	84.9	51.4	16.7	1.292	18.6	9.04	Benzine.
124	D. S. Brome	.9344	176.9	7.0	......	......	100.0	91.0	4.5	......	7.84		
125	John Gutendorf.	.9247	173.0	3.2	......	......	108.0	97.0	5.5	......	8.35		
126	P. H. Reardon.	.9324	174.8	3.2	......	......	126.4	111.2	7.6	......	.....	8.87	Turpentine.
128	Ilsley, Doubleday & Co.	.9332	176.7	6.3	......	......	109.1	94.5	7.3	......	8.18		
129	L. Kotzen.	.9337	165.4	10.5	......	......	106.1	87.3	9.4	......	7.83	4.39	Benzine.
130	Max Hurtwiz.	.9347	155.3	8.6	......	......	101.1	84.9	8.1	......	5.72		
54	....	.9351	186.0	6.1	......	......	115.2	104.8	5.2	......	4.00		
61	....	.9360	185.2	5.4	......	......	109.3	99.9	4.7	......	4.03		

ADULTERANTS.

						Mineral Oils.							
	Thompson & Bedford. .	.8436	7.8	....	......	......	14.4	6.4	4.0	......	.....	.....	"Venango" neutral oil.
						Resin-oil.							
42	John Smith's Son.	......	......	....	......	......	197.6	16.4	90.6	......	.....	.....	Third-run oil.
53	S. P. Shotter & Co....	......	10.8	....	......	......	93.7	6.3	43.7	......	.....	.....	Mystic brand lubricating-oil.
55	S. P. Shotter & Co....	.9664	34.7	17.6	73.3	46.2	101.9	8.3	46.8	5.685	.....	.....	"Boiled Java oil." A compound oil.
57	S. P. Shotter & Co....	.9881	17.5	....	63.9	40.3	92.3	7.7	42.3	5.231	.....	.....	Third-run oil.
						Menhaden-oil.							
56	Swan & Finch	......	189.6	3.8	178.8	112.7	114.5	96.5	9.0	1.169			
71	Wm. R. Winn.........	.9316	188.4	....	170.4	107.4	107.3	92.3	7.5	1.164			
103	Swan & Finch	.9307	......	....	175.4	110.6	110.1	97.9	6.1	1.129			
						Corn-oil.							
105	Elbert & Gardner.	.9242	......	....	......	......	76.2	73.8	1.2				
106	Glucose Sugar Co.	.9236	......	....	......	......	75.8	73.2	1.3				
111	Pope Glucose Co	.9241	......	....	......	......	75.4	71.6	1.9				
						Cottonseed-oil.							
32	....	......	......	....	......	......	65.8	62.2	1.8				
						Turpentine.							
143	Edward Smith & Co. ...	.8740	......	....	......	......	266.1	166.1	50.0				
						Benzine.							
142	Standard Oil Co.......	.7410	......	....	......	......	51.5	15.5	18.0	......	.....	.....	Called special naphtha.
146	A. H. Sabin...........	.7330	......	....	......	......	6.3	2.7	1.8	......	.....	.....	Turpentine substitute.
						Resin.							
144	Potter & Co.	......	......	....	......	......	161.4	8.0	76.7	......	.....	.....	Window-glass resin.
145	Potter & Co.	......	......	....	......	......	135.4	5.4	65.0	......	.....	.....	Black resin.

TABLE SHOWING THE ORDINARY FIGURES GIVEN BY LINSEED-OIL AND ITS ADULTERANTS.

	Specific Gravity at 150°.5 C.	Kœttstorfer Figure.	Acid Figure.	Hübl Figure.	Per Cent. Bromine Absorbed.	Bromine Addition Figure.	Bromine Substitution Figure.	Special Properties.
Linseed-oil, raw..	.931–.937	187–196	Less than 7	170–185	105–115	100–110	Less than 7	
Linseed-oil, boiled	.932–.950	186–196	Less than 7	170–185	105–115	100–110	Less than 7	
Mineral oil.	.800–.950	0	0	Less than 15	Less than 20	Less than 10	Less than 10	Unsaponifiable. May contain acids.
Resin-oil.	.970–1.000	Less than 20	Less than 20	40–60	90–200	Less than 20	40–100	Largely unsaponifiable.
Menhaden-oil....	About .931	About 189	Less than 10	160–180	105–115	90–100	5–10	High Maumené and low oxygen absorption figures.
Corn-oil.	About .924	About 189	Less than 10	115–125	About 75	About 72	About 2	
Cottonseed-oil....	.922–.930	191–197	Less than 10	106–111	About 65	About 62	About 2	
Turpentine.	About .873	0	0	....	About 265	About 165	About 50	Volatile with steam.
Benzine.	.730–.745	0	0	....	Less than 55	Less than 20	Less than 20	Volatile with steam.
Resin.	1.04–1.11	175–195	155–165	140–160	135–165	Less than 15	65–80	Separated by Twitchell's process.

CHAPTER VI.

LINSEED-OIL (*Continued*).

THE foregoing chapter, by Dr. McIlhiney, was a report to the New York State Department of Agriculture in 1901, and it seems best to supplement it by a brief report on the more important laboratory work which has been done since that time.

The analytical testing of linseed-oil for purity and quality has taken more definite form during the last few years. The Linseed-Oil Committee of Committee D–1 of the American Society for Testing Materials by co-operative work has been able to eliminate from practical consideration many of the tests which were considered more or less valuable prior to their doing the work. This has resulted in certain definite tests being agreed upon as covering in the main all that is required for the determination of the purity of linseed-oil made from North American seed. These tests are here reprinted from the proceedings of that society.

Dr. McIlhiney calls attention to the fact that in making up the Hanus solution for the determination of the iodine figure of linseed-oil, more attention should be paid than is commonly given or than is commonly insisted upon, to the proportions in which iodine and bromine are present in the solution. A failure to follow strictly the instructions given in the official method may result in obtaining a solution in which there is more bromine present than exactly enough to double the halogen content of the original solution as made by dissolving iodine in acetic acid, and in this case erroneous results are likely to be obtained. A slight excess of iodine does not appear to be harmful, though a slight excess of bromine is.

SPECIFICATIONS FOR RAW LINSEED-OIL.

I. PROPERTIES AND TESTS.

1. **Properties.**—Raw linseed-oil from North American seed shall conform to the following requirements:

	Maximum.	Minimum.
Specific Gravity at $\frac{15^\circ.5}{15^\circ.5}$ C. or	0.936	0.932
Specific Gravity at $\frac{25^\circ}{25^\circ}$ C.	0.931	0.927
Acid number	6.00	....
Saponification number	195	189
Unsaponifiable matter, per cent	1.50	....
Refractive index at 25° C.	1.4805	1.4790
Iodine number (Hanus)	....	180

II. METHODS OF TESTING.

2. **Methods of Testing.**—The recommended methods of testing are as follows:

General.—All tests are to be made on oil which has been filtered at a temperature of between 60° and 80° F. through paper in the laboratory immediately before weighing out. The sample should be thoroughly agitated before the removal of a portion for filtration or analysis.

Specific Gravity.—Use a pyknometer, accurately standardized and having a capacity of at least 25 cc., or any other equally accurate method, making a test at 15°.5 C., water being 1 at 15°.5 C., or a test at 25° C., water being 1 at 25° C.

Acid Number.—Expressed in milligrams of KOH per gram of oil. Follow the method described in Bulletin No. 107, revised 1908, Department of Agriculture, Bureau of Chemistry, page 142.

Saponification Number.—Expressed as with Acid Number. Blanks should also be run to cover effect of alkali in glass. Follow method given in Bulletin No. 107, revised 1908, Department of Agriculture, Bureau of Chemistry, pages 137–138.

Unsaponifiable Matter.—Follow Boemer's method taken from his Ubbelohde Handbuch der Oele und Fette, pages 261–262. "To 100 grams of oil in a 1000 to 1500-cc. Erlenmeyer flask add 60 cc. of an aqueous solution of potassium hydroxide (200 grams KOH dissolved in water and made up to 300 cc.) and 140 cc. of 95 per cent. alcohol. Connect with a reflux condenser and heat on the water bath, shaking at first until the liquid becomes clear. Then heat for one hour with occasional shaking. Transfer while yet warm to a 2000-cc. separatory funnel to which some water has been added, wash out the Erlenmeyer with water, using in all 600 cc. Cool, add 800 cc. of ether and shake vigorously one minute. In a few minutes the ether solution separates perfectly clear. Draw off the soap and filter the ether (to remove last traces of soap) into a large Erlenmeyer and distil off the ether, adding if necessary one or two pieces of pumice stone. Shake the soap solution three times with 400 cc. of ether, which add to the first ether extract. To the residue left after distilling the ether add 3 cc. of the above KOH solution, and 7 cc. of the 95 per cent. alcohol, and heat under reflux condenser for ten minutes on the water bath. Transfer to a small separatory funnel, using 20 to 30 cc. of water, and after cooling shake out with two portions of 100 cc. of ether; wash the ether three times with 10 cc. of water. After drawing off the last of the water, filter the ethereal solution so as to remove the last drops of water, distil off the ether, dry residue in water oven and weigh."

Or, any accurate method involving the extraction of the dried soap may be used.

Refractive Index.—Use a properly standardized Abbé Refractometer at 25° C.; or any other equally accurate instrument.

Iodine Number (Hanus).—Follow the Hanus method as described in Bulletin No. 107, revised 1908, Department of Agriculture, Bureau of Chemistry, page 136.

SPECIFICATIONS FOR BOILED LINSEED-OIL.

I. PROPERTIES AND TESTS.

1. **Properties.**—Boiled linseed-oil from North American seed shall conform to the following requirements:

	Maximum.	Minimum.
Specific Gravity at $\frac{15°.5}{15°.5}$C.	0.945	0.937
Acid number	8	....
Saponification number	195	189
Unsaponifiable matter, per cent	1.5	....
Refractive index at 25° C	1.484	1.479
Iodine number (Hanus)	....	178
Ash, per cent	0.7	0.2
Manganese, per cent	....	0.03
Calcium, per cent	0.3	....
Lead, per cent	....	0.1

2. **Methods of Testing.**—The recommended methods of testing are as follows:

General.—The sample should be thoroughly agitated before the removal of a portion for analysis.

Specific Gravity.—Use a pyknometer, accurately standardized and having a capacity of at least 25 cc., or any other equally accurate method, making a test at 15°.5 C., water being 1 at 15°.5 C.

Acid Number.—Expressed in milligrams of KOH per gram of oil. Follow the method described in Bulletin No. 107, revised, 1908, Department of Agriculture, Bureau of Chemistry, page 142.

Saponification Number.—Expressed as with Acid Number. Blanks should also be run to cover effect of alkali in glass. Follow method given in Bulletin No. 107, revised 1908, Department of Agriculture, Bureau of Chemistry, pages 137–138.

Unsaponifiable Matter.—Follow Boemer's method taken from his Ubbelohde Handbuch Der Ole u. Fette, pages 261–262. "To 100 grams of oil in a 1000 to 1500-cc. Erlenmeyer flask add 60 cc. of an aqueous solution of potassium hydroxide (200 grams KOH dissolved in water and made up to 300 cc.) and 140 cc. of 95 per cent. alcohol. Connect with a reflux condenser and heat on the water bath, shaking at first until the liquid becomes clear. Then heat for one hour with occasional shaking. Transfer while yet warm to a 2000-cc. separatory funnel to which some water has been added, wash out the Erlenmeyer with water, using in all 600 cc. Cool, add 800 cc. of ether and shake vigorously one minute. In a few minutes the ether solution separates perfectly clear. Draw off the soap and filter the ether (to remove last traces of soap) into a large Erlenmeyer and distil off the ether, adding if necessary one or two pieces of pumice stone. Shake the soap solution three times with 400 cc. of ether, which add to the first ether extract. To the residue left after distilling the ether add 3 cc. of the above KOH solution, and 7 cc. of the 95 per cent. alcohol, and heat under reflux condenser for ten minutes on the water bath. Transfer to a small separatory funnel, using 20 to 30 cc. of water, and after cooling shake out with two portions of 100 cc. of ether; wash the ether three times with 10 cc. of water. After drawing off the last of the water, filter the ethereal solution so as to remove the last drops of

AVERAGE RESULTS ON BOILED OIL.

Sample No.	Specific Gravity.	Iodine Number.	Acid Number.	Saponification Number.	Refractive Index at 25° C.	Percentage of				
						Unsaponifiable Matter.	Ash.	Manganese.	Lead.	Calcium.
24	0.9422	181.3	7.99	191.0	1.4831	0.836	0.366	0.064	0.104	0.018
25	0.9472	178.9	6.34	192.2	1.4841	0.885	0.642	0.040	0.372	0.023
27	0.9393	186.7	5.87	192.0	1.4843	0.650	0.228	0.047	0.055	0.017
29	0.9440	180.1	5.00	191.9	1.4825	0.597	0.590	0.052	0.290	0.019
32	0.9371	178.6	3.54	191.6	1.4814	1.12	0.346	0.086	0.066	0.025
33	0.9427	181.2	7.14	192.9	1.4802	1.09	0.518	0.056	0.284	0.015
34	0.9371	181.0	3.35	192.6	1.4806	1.02	0.244	0.044	0.053	0.021
35	0.9396	184.9	5.01	191.6	1.4794	1.16	0.319	0.077	0.060	0.012
Aver. .	0.9411	181.6	5.53	191.9	1.4819	0.919	0.406	0.058	0.160	0.018
Max. .	0.9472	186.7	7.99	192.9	1.4843	1.16	0.642	0.086	0.372	0.025
Min. .	0.9371	178.6	3.35	191.0	1.4794	0.597	0.228	0.040	0.053	0.012

water, distil off the ether, dry residue in water oven and weigh."

Or, any accurate method involving the extraction of the dried soap may be used.

Refractive Index.—Use a properly standardized Abbé Refractometer at 25° C., or any other equally accurate instrument.

Iodine Number (Hanus).—Follow the Hanus method as described in Bulletin No. 107, revised 1908, Department of Agriculture, Bureau of Chemistry, page 136.

Ash.—The determination of the percentage of ash and the constituents thereof may be made by any method which gives accurate results.

The following remarks on these tests are by various members of the committee.

In the matter of specific gravity the important work that has been done has been to establish the temperature at which the specific gravity should be reported. The specific gravity may be determined at any temperature and the tables and formulæ furnished in the reports of Committee D–1 are very valuable for the calculating of the specific gravity from one temperature to that of another.

H. Wolff's method for rosin (C.A., 8, No. 13, p. 2475, 1914) is carried out as follows:

Dissolve 2.5 grams of the total fatty matter in 10 to 20 cc. of absolute ethyl alcohol, then add 5 to 10 cc. of a solution of one volume strong sulphuric acid and four volumes absolute alcohol and boil for two to four minutes under a reflux condenser. Add to the liquid about five times its volume of 7 to 10 per cent. sodium chloride (NaCl) solution and extract with ether. Shake out the aqueous portion two or three times with ether. Unite the ether solutions and wash with sodium chloride solution until the washings are neutral. Add alcohol and titrate the rosin acids with N/4 NaOH. An error which Wolff states is constant is provided for by calculating according to the following formula: $x = 8.65a/M - 1.5$, where x = percentage of rosin acids, a = number cubic centimeters of N/4 NaOH, and *m*=weight of fatty matter taken.

Particular attention is called to a modification of the Twitchell method prepared by G. W. Thompson for the determination of resin acids in linseed oil.

GENERAL OUTLINE OF METHOD FOR ROSIN IN BOILED OIL.

A quantity of oil is weighed into a separatory funnel and thinned with ether. The bases are separated by treating the oil in ether with HCl (1 : 1). To the washed solution remaining in funnel, alcohol is added and a definite excess of alkali; water is added and all of the rosin and a small amount of oil and its acids shaken out. The soap solution is drawn off and the fatty and resin acids separated and washed in the usual manner. Finally the combined acids are dissolved in alcohol and the Twitchell method followed out in detail, determining the resin, volumetrically.

The method is carried out as follows:

Twenty-five grams of oil are thinned with 75 cc. of ether, 50 cc. of HCl (1 : 1) added, and the mixture thoroughly shaken, allowed to separate and the acid layer drawn off; the oily layer then washed twice with water, using a salt solution to break up any emulsion formed. To the washed ether layer 25 cc. of alcohol are added and a few drops of phenolphthalein. Now, a normal solution of KOH is run in until, after thorough shaking, a permanent pink color is obtained; 100 cc. of water are then added and 5 cc. more of the normal alkali. The excess is kept constant. The whole is agitated for a couple of minutes, then allowed to settle out; the soap solution is drawn off and the oily layer again treated with 25 cc. of alcohol, 50 cc. of water, and 1 cc. of normal KOH. This is shaken and allowed to separate, the second soap solution drawn off, and the oil layer washed three times with water and alcohol (1 : 1).

This treatment will remove all the rosin and a small amount of fatty acids. The soap solution is evaporated on the steam bath, dissolved in water and made acid; the fatty and rosin acids are separated as usual, dissolved in ether and thoroughly washed with water. The solution of fatty and rosin acids is filtered into a flask and the ether distilled off; the dry fatty and rosin acids are dissolved in absolute alcohol and then treated by the Twitchell method for rosin.

In working this method on samples of known rosin contents, the following results were found:

	Rosin in Oil, per Cent.	Rosin Found by Foregoing Method, per Cent.
Sample No. 1	0.5	0.64
Sample No. 2	1.0	1.17
Sample No. 3	3.0	3.04
Sample No. 4	5.0	4.90

It was necessary to make a slight correction for acidity in a pure oil run through by this method. Further work may show a way to make this allowance unnecessary.

Correction in this set of samples, 0.59 per cent.

Storing raw linseed-oil in sealed containers for a period of five years has made no appreciable change in any of the original figures save that of the acid number, which is higher. Oil from 1913 crop North American seed possesses constants practically the same as oil from other crops which the committee has reported. This shows uniformity of oil produced year by year in the same locality.

The iodine number of the fresh fatty acids from a linseed-oil averages on the six raw oils 3.1 per cent. higher than the same figure on the oil. The greatest difference is 3.73 per cent., while the lowest is 2.13 per cent. It is valuable to know the limits for the iodine number on the fatty acids, because often the oil, if extracted from paints, has been so affected by the treatment accorded it that its iodine number is no proof of its purity; while if the acids from this same oil can be obtained, they will give normal figures. This is true, for instance, of oils extracted from paste or liquid paints.

A new test in which the Committee has done some work is the hexabromide test. The work done by Eibner is monumental in its completeness. The method finally devised by him, however, while satisfactory in the hands of experienced operators, does not give good results without very careful manipulation.

The following is a translation of part of his article in the Farben-Zeitung of Nov. 23, 1912.

DESCRIPTION OF NEW METHOD FOR DETERMINATION OF HEXABROMIDE NUMBER OF LINSEED-OIL FATTY ACIDS.

The determination of the hexabromide number is preceded by the preparation of free fatty acids.

1. **Preparation of Pure Linseed-oil Fatty Acids.**—Three and one-half grams of the linseed-oil are weighed into each of three round-bottom evaporating dishes of about 220-cc. capacity. Then, 45 cc. of one-half-normal alcoholic potash are added in each case and the dishes are placed on the water bath. This is brought slowly to boiling. The oil is frequently stirred with a glass rod, flattened at the end. By this method, the saponification is better and more quickly accomplished.

The alcoholic potash is prepared as follows: 28 grams of solid pure caustic alkali are placed in a 1-liter measuring cylinder and dissolved in from 30 to 40 cc. of distilled water; then, 97 per cent. ethyl alcohol is added, to make the volume 1 liter. The solution is allowed to stand for two or three days to settle out any cloudiness due to potassium carbonate. This potash solution is best kept in a brown bottle, stoppered with a rubber stopper.

The water bath is not warmed until the evaporating dishes are filled. The saponification process begins slowly and gradually, so that the alcoholic soap solution does not crawl to the rim of the evaporating dishes, thereby causing losses. The contents of the dishes are evaporated to dryness, with constant stirring and breaking up of the nearly dry soaps. In this way, the alcohol is completely removed. This whole operation of saponification and evaporation will take from one to one and one-half hours. The resulting product will be a light yellow, agreeable-smelling soap powder. The soap which first comes to dryness is mixed with 50 cc. of hot water, and dissolved on the boiling water bath. This requires about five minutes. This soap solution is added to the soap which next comes to dryness, and the first evaporating dish is rinsed out with water. Finally, this solution is added to the soap which last comes to dryness. The whole soap solution is cooled off somewhat and poured into a 1-liter separatory funnel, graduated at 180 cc. and 340 cc. The volume of the soap solution must now amount to 180 cc. and must not be any greater. The light yellow soap solution, which is absolutely clear in a warm state, is now cooled down to the temperature of tap water, whereby it becomes slightly cloudy. By the addition of 20 cc. of five-normal sulphuric acid, the linseed fatty acids are freed, and float on top of the liquid. They have an agreeable, characteristic odor and are, in the beginning, precipitated in an opaque, white form. After a few seconds, the emulsion disappears. The acids then are plainly yellow. The contents of the separatory funnel are now thoroughly shaken with 140 cc. of ether (second mark at 340 cc.), during which operation the cock is opened at least once to avoid excessive pressure. After five minutes, the aqueous solution is drawn off as much as possible, the yellow ether solution of fatty acids is gently rotated and allowed to stand for a minute. After this operation, a little more water will settle in the lower part of the separatory funnel, and is removed. After adding 70 grams of anhydrous Glauber's salt, the fatty-acid solution is allowed to stand overnight in the separatory funnel.

The detailed operation is as follows: Saponification should not be started until the afternoon. After setting free the fatty acids with sulphuric acid, 100 cc. of ether are first used for shaking out and allowed to stand. The aqueous solution is drawn off into a second separatory funnel, and then shaken out again with 40 cc. of ether. The combined ether solutions of fatty acids are then to be further treated as mentioned above.

The next forenoon, the recovery of the pure fatty acids is undertaken. For this purpose, a tared Erlenmeyer flask of 200-cc. capacity is used. The flask is stoppered with a well-pressed, two-holed, cork stopper. In one of the holes is inserted a 50-cc. dropping funnel, which supports an ordinary small funnel. In the other hole is placed a glass tube of 0.5-cm. bore, bent at a right angle, and this is connected with a Liebig condenser.

The dried ether solution of fatty acids is now filtered through a dry, folded filter ($d = 18.5$ cm.) into a 150-cc. Jena Erlenmeyer flask and from there is poured into the dropping funnel. Then about 100 cc. of this solution are run into the 200-cc. flask and the water bath is slowly warmed to about 70° C. As the ether is distilled off, more of the solution is added, drop by drop. The distilled ether is used to extract the Glauber's salt in the separatory funnel, which has absorbed a considerable amount of fatty acids. This is done six times, using from 100 to 120 cc. of ether each time. The fifth extraction is, as a rule, entirely colorless. Finally, by means of an ether wash-bottle, the folded filter, the flask used to receive the filtrate, the small funnel, and the dropping funnel are rinsed off, in order to recover quantitatively the fatty acids adhering to them. After the largest part of the ether is distilled off, the water bath is brought to boiling, and a few more cubic centimeters of ether will then be distilled off.

The extraction of the Glauber's salt and the distilling off of the ether take about 1½ hours. Even after ether has ceased to distil over, the fatty acids still contain some of it. Next, the flame of the water bath is extinguished, the Liebig condenser and dropping funnel are removed, and a tight-fitting stopper, with gas inlet and outlet tubes, is inserted in the flask. The end of the former tube is placed 1 cm. above the surface of the fatty acids. The outlet tube is drawn out to a capillary to prevent the hydrogen gas, which circulates above the fatty acids, from escaping too quickly, and to force it to mix with the ether vapors before leaving the flask. The hydrogen is first purified by passing it through an alkaline lead salt solution and then through concentrated sulphuric acid. The flask is replaced on the water bath, which is kept boiling vigorously. In order to drive off the ether, two hours are required. From four to five gas bubbles per second should pass through the flask. Experiments made with carbon dioxide instead of hydrogen give the same results, but we prefer to use hydrogen. Next, the fatty acids are removed from the water bath, and, with a clean cloth, the hot flask is wiped off on the outside and inside around the top of the neck; then, while warm, it is put in a vacuum desiccator. This is evacuated to a high degree and then left standing for at least four hours. By this means, the fatty acids, as a rule, become partly solid. They are then weighed very quickly and put in a vacuum as before. After two hours, the flask is again weighed as quickly as possible, the weights having previously been put on the balance. Finally, the desiccator with flask is once more evacuated, and left standing overnight. The next morning, the weight of the flask is checked.

2. **Preparation of the 10 per cent. Ether Solution of Fatty Acids.**—From the 9 to 10 grams of weighed linseed-oil fatty acids, a 10 per cent. ether solution is now made. Forty cubic centimeters of ether, dried over calcium chloride, are added to the fatty acids, and carefully shaken until the latter are dissolved. This solution is poured quantitatively into an accurately graduated 100-cc., glass-stoppered, measuring cylinder, the gradua-tion marks of which run half way around the circumference of the cylinder, whereas those for every 10 cc. run entirely around the cylinder. By means of an ether wash-bottle, the empty flask is washed with 20 cc. of ether, well shaken, and this liquid also is poured into the cylinder. The flask is then rinsed again, and care is taken to wash off whatever ether solution has run down on the outside. Then the cylinder is filled up nearly to the 100-cc. mark and shaken. The glass stopper is raised for a moment, and, after a minute, the cylinder is filled to the mark and thoroughly shaken once more. The lower meniscus is read.

3. **The Brominizing Process.**—By means of a standardized pipette, marked at the top and bottom, 20 cc. of the freshly shaken fatty-acid solution are removed from the graduated cylinder and placed in a 100-cc. Jena Erlenmeyer flask with not too narrow a neck. This 20 cc. should contain from 1.9 to 2 grams of fatty acids. A cork stopper, with a groove cut in the side, is placed in the flask, and then the latter is put in a cooling mixture of a tem-

perature not exceeding −10° C. This mixture is prepared in a suitable vessel, such as a water bath, by mixing finely broken ice with the necessary quantity of salt, and thoroughly stirring the mixture with a strong glass rod. In winter, snow can be used. The cooling mixture must be so made that the flask can be easily moved in it. After leaving the ether solution in the cooling mixture for ten minutes, it will have the desired temperature. In the meantime, 1 cc. of commercial bromine is placed in the brominizing burette. A 10-cc. burette, or even a smaller one, is the most suitable, but the glass cock must be well ground in, and the delivery point must be fine. Before brominizing, the flask containing the fatty-acid solution must be shaken slowly in the cooling mixture. Five-tenths cubic centimeter of bromine—half of the quantity to be used—is added in single drops, and then the other 0.5 cc. of bromine, in double drops, keeping the flask cold throughout the operation by carefully shaking it in the cooling mixture. The detailed method of procedure is as follows: The cock of the burette is slowly opened, permitting a single drop of bromine to run down the side of the flask, thereby preventing loss by spattering. The cock of the burette is then closed, and the flask is shaken in the cooling mixture. After from 12 to 15 drops of bromine have been added in this manner, the hexabromide of linolenic acid generally begins to precipitate in the form of a fine crystalline powder, which settles quickly. With every additional drop, the precipitate can be plainly seen to increase. After 0.5 cc. of bromine has been added in single drops, which should take approximately twenty minutes, the other 0.5 cc. is added in double drops in exactly the same manner. This will take ten minutes, so that the entire brominizing process will consume thirty minutes. After cooling for two minutes longer, the flask is again shaken and then allowed to stand stoppered for two hours in the cooling mixture. Over the precipitate can be seen a reddish brown fluid, a proof of the excess of bromine in the reaction mixture. Quite frequently, it is observed that some of the precipitate adheres to the sides of the flask, due perhaps to the intense cooling. This, however, cannot be avoided, and does not influence the quantitative recovery of the precipitated hexabromide. The time for brominizing, thirty minutes, must be strictly adhered to and must not be shortened. The added bromine disappears almost immediately, until an excess has been added. During the two-hours standing, the temperature may rise somewhat, but in order to avoid secondary reactions as far as possible, it should never exceed $-5°$ C. In the meantime, the washing ether is prepared. Five cubic centimeters of ether are put in each of 5 test tubes, which are stoppered and set in the cooling mixture. For filtering, a Daniel filtering tube is used, which is provided with an asbestos pad, made as thin and uniform as possible. Two grams of Kahlbaum's asbestos, suspended in 500 cc. of water, will be sufficient for a series of determinations. On the top of the asbestos a perforated porcelain plate is placed, the diameter of which must be almost as large as the inside diameter of the filtering tube. The perforated plate has about 20 round openings, 2 mm. in diameter. One liter of distilled water is drawn slowly through the tube, and the latter, with its cover, is then dried for one hour at 110° C., allowed to cool for an hour in the desiccator, and then weighed. In weighing the tube is suspended by an aluminum wire. After the bromide precipitate has stood for two hours in the cooling mixture, it is filtered. The tared filtering tube is connected with a filtering flask, which, however, during the whole filtering process, is not connected with the pump. After making sure once more that the cooling mixture is at the proper temperature, the operator removes the flask containing the hexabromide and wipes it off with a dry cloth, without disturbing the precipitate. With the assistance of a glass rod, and without disturbing the precipitate, the mother-liquor is now carefully poured upon the filter and allowed to drain through completely. In the meantime, the precipitate is thoroughly shaken with the first 5-cc. portion of washing ether and left to settle in the cooling mixture. The ether becomes reddish brown; the precipitate becomes lighter. Immediately after the mother-liquor has run through the filter, the washing liquid in the flask is poured upon the filter, care being taken, however, to retain all the precipitate in the flask. The filter must never become dry, as this would cause a considerable delay in filtering.

The precipitate is then thoroughly mixed with the second 5-cc. portion of ether and brought, as completely as possible, upon the filter, immediately after the first portion of washing ether has drained through. The precipitate settles immediately, and above it is a yellow solution which filters easily.

The flask is then cleaned with a feather, using the third 5-cc. portion of ether. Next, the precipitate still remaining in the flask is stirred up and brought upon the filter immediately after the preceding washing liquid has drained through. Then, the precipitate on the filter is stirred with a glass rod and is thus freed as much as possible from the mother-liquor. At this point, the washing ether, filtering through, still has a yellowish color, but the precipitate is almost white. The flask is again cleansed with the feather, using the fourth portion of ether. The latter, which is then colorless and contains only a trace of precipitate, is also poured upon the filter, in such a way as to rinse the rim of the filtering tube, up to which some of the mother-liquor has crawled during filtration. The precipitate on the filter is once more stirred up with the glass rod. The ether filtering through is now, in most cases, very faintly yellowish or colorless. Then the last 5-cc. portion of ether is used to rinse the flask once more. The glass rod is now cleaned with the feather, and the entire contents of the flask are brought upon the filter and allowed to run through. Then, with the filtering tube half covered, the filtering flask is connected with the suction pump, and the latter is worked strongly for one minute. The hexabromide shrinks to a very nice white mass. Occasionally, cracks occur in the precipitate. A small quantity of a slightly yellowish fluid is drawn from the bromide by the suction process, and the lower part of the filtering tube often becomes somewhat clouded with a small amount of residue left after the washing ether has evaporated. The filtering tube is now removed from the filtering flask, wiped off outside, and heated in a drying oven for two hours at from

80 to 85° C. Then it is allowed to cool for one hour in the desiccator and is weighed. It has often been observed that a hexabromide, which would be snow white in color, if dried at 80° C., becomes gray on the surface, if dried at 100° C. During filtration, especially during the first half of it, the precipitate must never become dry. Should this happen before the hexabromide is thoroughly pure, it can hardly be washed out completely, as sticky substances, bromides of various compositions, which, once dried, are difficult to dissolve in ether, adhere to the original precipitate. Before drying, the precipitate must be white, inside and out. If it shows a yellow color anywhere, it will partially melt during the drying process and become gray on the surface. The weight will then be somewhat too high. The filtering, as a rule, takes from ten to fifteen minutes and should not, at all events, exceed twenty-five minutes. The condition of the asbestos greatly influences the period of filtration. The hexabromide number is obtained by calculating the weight of hexabromide per 100 grams of fatty acids.

Following is a summary of the points which may have been responsible for errors in hexabromide determination.

1. Bromination at too low a temperature. The precipitate seems to be more crystalline or coarser and therefore filters more easily when formed at a temperature not lower than −10° C.

2. Failure to wash the asbestos pad free of mother liquor before any more precipitate is added thereto.

3. Failure to keep the pad and precipitate wet with ether at all times by making each addition of precipitate or washing ether, immediately upon the liquid being filtered off.

4. Failure to keep the acids protected from the air from the moment they are removed from the atmosphere of hydrogen until brominated. They change rapidly in a manner that lowers their content of insoluble hexabromides.

The hexabromide method is now so accurate that the hexabromide numbers of the fatty acids obtained by two separate saponifications of the same linseed-oil check within 1 per cent. For two determinations run on the same fatty acid solution, the maximum difference is not more than 0.6 per cent. This accuracy is sufficient, as this is a complicated method involving many operations. All determinations by this method with various linseed-oils have given very satisfactory results. For instance, with two different saponifications of the same oil, the maximum difference was only 0.7 per cent. For the purpose of control, we had the hexabromide number of a linseed-oil determined by disinterested parties. An average of 54.10 per cent. was found. Two weeks later, we had the hexabromide number of the same linseed-oil determined again, and this time the result was 54.21. Two determinations on the same linseed-oil gave, as an average, a hexabromide number of 53.66.

It is important, for technical work, to obtain analytical results as quickly as possible. Consequently, we tried to make the hexabromide method more rapid without sacrificing its accuracy.

We saponified the linseed-oil in the morning in the usual manner, prepared the ether solution of fatty acids, and let it stand over the Glauber's salt until three in the afternoon (four to five hours). Then the fatty acids were freed from ether and treated with hydrogen for two hours. The pure fatty acids were left overnight in a highly evacuated desiccator. By quickly weighing in the morning, the weight of acids was ascertained, and then we began the determination of the hexabromide number, so that the result was obtained during the afternoon. In the meantime, the iodine number and saponification number could have been determined, and also a qualitative test could have been made. So a pure linseed-oil should be analyzed within two days, excepting in cases where the oil is to be tested for rapeseed-oil, in which case the separation and identification of erucic acid became necessary. Saponification could also be started in the afternoon, giving the ether solution of fatty acids a chance to stand overnight with anhydrous Glauber's salt. The next day, the free fatty acids could be left in the desiccator until afternoon, but at least four hours should be allowed.

Thompson makes the following remarks on the use of this method:

In the determination of the hexabromide number, Eibner's method was followed in detail for the recovery of the fatty acids. Instead of preparing a 10 per cent. solution of the fatty acids in ether, as recommended by Eibner, I found the following procedure to give equally accurate results, especially in warm weather, when ether solutions are difficult to handle.

The pure fatty acids were poured into small vials holding approximately 2 grams when full and tightly corked. In this way, the fatty acids can be preserved for a considerable period without appreciable change. To make the test, the contents of one of the vials was poured into a weighed Erlenmeyer flask of 100-cc. capacity, flask and contents reweighed, and the fatty acids dissolved in 20 cc. of ether. I found 1.9 to 2 grams a convenient quantity to work with.

The brominizing process was carried out exactly as prescribed by Eibner. Four determinations were generally made at once, that is, four flasks were placed in a large bath of freezing mixture, allowed to reach a temperature of $-10°$ C., then bromine was added, one drop at a time, first to flask No. 1, then to flask No. 2, and so on until 0.5 cc. had been added to each flask. This required about 20 minutes. The second 0.5 cc. of bromine was added two drops at a time, and where four determinations are run at once, this will require between ten and fifteen minutes. The advantage of working with this number is that there is no delay and little danger of adding the bromine too rapidly. The time consumed for brominizing four tests was about thirty minutes. For measuring the bromine, I used a small burette, which could be conveniently held in one hand.

After the flasks had stood in the freezing mixture at $-10°$ C. for two hours, the filtering and washing was carried out as follows: A small wash bottle containing ether was placed in a separate freezing bath and the contents cooled to $-10°$ C. The tip of the bottle was made to deliver a very fine stream. The time required to deliver the proper amount of wash ether was determined by experiment and can be judged very closely.

The flask was removed from the freezing bath and the mother liquor carefully decanted. The precipitate was then washed down with a fine stream of ether, using about 5 cc., and the precipitate and wash ether shaken thoroughly and allowed to settle out in the freezing bath. This washing by decantation was repeated three times. The precipitate was then transferred to a Gooch crucible, and the flask was washed out with about 5 cc. of ether. It is seldom that any precipitate will be found adhering to the flask, but if such is the case, it can be removed with an ordinary rubber policeman. The precipitate on the Gooch crucible was allowed to drain, using a gentle suction if necessary, but care should be taken to prevent the precipitate from becoming dry. Washing was continued on the Gooch crucible, stirring up the precipitate each time with a fine stream of ether, and allowing it to drain almost dry, until the wash ether appeared colorless. Strong suction was then applied and the precipitate freed from the liquid. The Gooch crucible was removed and placed in a steam bath which was held at 80° C., and dried for one hour. The liquid in the filtering flask will be found to be about 50 cc., and should not exceed this amount.

In following out this method results have been obtained which agreed closely with those reported by Eibner.

Much interesting work has been done in the study of the products of the oxidation of linseed-oil.

It seems probable that during the oxidation of linseed-oil, the character of the film produced depends very largely upon atmospheric conditions, and that the water, which is one of the products of oxidation, may be held in loose combination, and will have a great effect upon the durability of the paint. It is likely that certain decomposition products are occasionally formed in the oxidation of linseed-oil, one of its products being azelaic acid. The conditions under which azelaic acid is formed have not been fully studied, but inasmuch as azelaic acid is of very much lower molecular weight than the acids normally constituents of linseed-oil, if it is formed it will probably modify the character of paint films very considerably.

Some of the most recent work on oxidation is described in the following:

ABSTRACT OF A PAPER BY G. W. THOMPSON ON "CHANGES IN THE VOLUME AND SPECIFIC GRAVITY OF LINSEED-OIL FILMS ON DRYING," READ BEFORE THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS IN JANUARY, 1916

The purpose of this investigation was to determine whether any change took place in the volume and specific gravity of linseed-oil and linseed-oil paints during the drying after having been applied in thin films in the usual way. It is a well-known fact that linseed-oil when spread in a thin film changes from a liquid to a semi-solid substance and that during this change oxygen is absorbed from the air and carbonic acid, water, and other decomposition products are given off.

A. H. Sabin * conducted an elaborate set of tests in which he showed the change in weight occurring during the drying of paints applied to 4 by 5-in. glass plates, and constructed curves which indicated that in many cases the increase in weight amounted to as much as 18 per cent., and that after the maximum increase in weight had occurred, there was a gradual decrease in weight so that in some cases the weight of the dried oil film finally was close to that of the oil when originally applied. This indicated first an absorption of oxygen with subsequent giving off of products of oxidation and decomposition.

J. C. Olsen and A. E. Ratner † conducted experiments to determine the increase in weight of linseed-oil on drying, and also the amount of carbon dioxide and water given off. They found that at the end of seventy-four days the oil had increased in weight 18.05 per cent., that 5.21 per cent. of carbon dioxide and 14.55 per cent. of water had been given off. As the carbon in the carbon dioxide and the hydrogen in the water came from the linseed-oil they concluded that the sum of the increase in weight

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* German and American Varnish Making, Bottler and Sabin, p. 194 (Wiley).

† Vol. V, p. 100. Transactions of Am. Inst. of Chem. Engs., 1912.

of the oil and the carbon dioxide and the water given off would represent the actual amount of oxygen that had entered into combination with the oil and its constituents. This sum amounted to 37.81 per cent.

It was evident to Mr. Thompson that these chemical changes could not take place without corresponding physical changes, particularly in specific gravity and volume. He therefore arranged with one of his assistants, Mr. Arthur G. Belden, in the laboratory of the National Lead Company, to conduct an investigation similar to that of A. H. Sabin referred to, which was to apply to 4 by 5-inch glass plates coatings of linseed-oil and various paints, observing the change in weight which took place on the exposure of these plates to the action of clean air. He went further, however, and determined the volume of the glass plates he used by weighing in water, and knowing the specific gravity of the oils and paints used, he was able to calculate their volumes from the amounts taken.

After the plates had been exposed for two hundred days and the weighings necessary for the oxidation curves made, the plates were again weighed in water, by which the final volumes of the films were determined. From these final film volumes the specific gravities of the oxidized films were calculated. It was assumed that no change in volume, weight or specific gravity of the pigments had taken place and that the changes took place entirely in the oil in the films. In this weighing no correction was made for the buoyancy of the air. Calculation indicated, however, that this buoyancy would have had no effect within the reported limits.

The striking feature about these tests is that the specific gravities of the linseed-oils used have increased from 23 to 37 per cent., and the volume has decreased from 12 to 23 per cent. The shrinkage in volume must have a bearing upon the durability of paints.

This work was undertaken for the definite purpose of finding out just what changes in specific gravity and volume occurred. It would be very desirable of course if a paint vehicle could be developed in which the changes in volume would be reduced to a minimum.

The testing of tung- (or Chinese wood-) oil has been a matter of much difficulty. Much work has been done, and many methods proposed, which have not given concordant results in the practice of different analysts. So far, the most satisfactory procedure is embodied in the

AMERICAN SOCIETY FOR TESTING MATERIALS

SPECIFICATIONS FOR TUNG- OR CHINESE WOOD-OIL.

1. **Properties.**—Raw tung-oil shall conform to the following requirements:

	Maximum.	Minimum.
Specific gravity at $\frac{15°.5}{15°.5}$ C.	0.943	0.939
Acid number	6	
Saponification number	195	190
Unsaponifiable matter, per cent	0.75	
Refractive index at 25° C.	1.520	1.515
Iodine number (Hübl 18 hours)	......	165
Heating test (Browne's Method), minutes	12	
Iodine jelly test, minutes	4	

2. **Methods of Testing.**—The recommended methods of testing are as follows:

Specific Gravity.—Use a pyknometer accurately standardized and having a capacity of at least 25 cc., or any other equally accurate method, making the test at 15°.5 C., water being 1 at 15°.5 C.

Acid Number.—Weigh 10 grams of oil in a 200-cc. Erlenmeyer flask, and add 50 cc. of neutral alcohol, connect with a reflux air condenser (or place small funnel in neck of flask), and heat on a steam bath for one-half hour. Remove from the bath, cool, add phenolphthalein, and titrate the free acid with N/5 sodium hydroxide. Calculate as the acid number (milligrams of potassium hydroxide to 1 gram oil).

Saponification Number.—Weigh from 2 to 3 grams of oil in a 200-cc. Erlenmeyer flask, add 30 cc. of a N/2 alcoholic solution of potassium hydroxide, connect with a reflux condenser, heat on a steam bath for one hour, then titrate with N/2 sulphuric acid, using phenolphthalein as indicator. Always run two blanks with the alcoholic potash. From the difference between the number of cubic centimeters of acid required by the blanks and the determinations, calculate the saponification number (milligrams of potassium hydroxide to 1 gram of oil).

Unsaponifiable Matter.—To 25 grams of oil add 15 cc. of an aqueous solution of KOH (200 grams of KOH dissolved in water and made up to 300 cc.) and 35 cc. of 95 per cent. alcohol. Connect with a reflux condenser and heat on the water bath for one hour with occasional shaking. Transfer to a separatory funnel containing a little water and wash out flask with water, using in all 125 cc. Cool, add 200 cc. of ether and shake vigorously for one minute. In a few minutes the ether solution will separate perfectly clear. Draw off the soap solution into another separatory funnel. Shake the soap solution with three 100-cc. portions of ether. Unite all the ether portions and wash with three 30-cc. portions of water. Filter the ether solution (small portions at a time) into a tared flask, distil off the ether and dry flask and contents to constant weight at 95° to 100° C. in a steam oven. Report the percentage of unsaponifiable matter.

Refractive Index.—Use a properly standardized Abbé refractometer at 25° C., or any other equally accurate instrument.

Iodine Number (Hübl).—Place a small quantity of oil into a small weighing bottle or beaker. Weigh carefully. Transfer by dropping from 0.2 to 0.3 gram to a 500-cc. bottle having a well-ground stopper, or a specially flanged neck, iodine-test Erlenmeyer flask. Reweigh the weighing bottle or beaker to determine the amount of oil used in the test. Then dissolve the oil in 10 cc. of chloroform and add an amount of Hübl solution containing twice the amount of iodine that will be absorbed by the oil. Stopper the flask, shake well, and place in a dark closet for eighteen hours. Add 20 cc. of a 10 per cent. solution of potassium iodide and 100 cc. of distilled water. Titrate with N/10 sodium thiosulphate, using starch as an indicator. Blank tests must be made. From the difference between the amounts of sodium thiosulphate required by the blanks and the determination, calculate the iodide number (centigrams of iodine to 1 gram of oil).

On account of the fact that Hübl solution after preparation is apt to deteriorate in strength, it is considered advisable to have prepared the two component parts of Hübl solution, namely, a solution of mercuric chloride in alcohol and a solution of iodine in alcohol, of the proper strength, as outlined in text-books. The proper amounts of these solutions may be mixed on the day of use.

Heating Test (Brown's Method).—Test tubes for containing the oil should be 16 cm. by 15 mm., with a mark near the bottom to indicate 5 cc., and closed by a cork so perforated that a glass rod 3 mm. in diameter could move freely.

Fill a copper beaker (height, 12 cm.; internal diameter, 6 cm.) with cottonseed-oil to a height of 7.5 cm. Place a thermometer so as to be 1.5 cm. from the bottom of the bath.

Use a nitrogen-filled, immersed-stem chemical thermometer, engraved stem; total length 4 to 4½ ins.; graduated from 210° to 310° C. in 2° intervals; the length between 210° and 310° C. not less than 2½ ins. If preferred, use emergent-stem thermometer 30 cm. long, with graduations from 100° to 400° C., making correction for emergent stem according to the method outlined in Stem Correction Sheet No. 44 of the U. S. Bureau of Standards.

When the bath temperature is 293° C. (560° F.) and very slowly rising at this point, place the tube containing 5 cc. of the oil to be tested so that its bottom is level with the lowest part of the bulb of the thermometer. Note the time, remove the source of heat for about forty-five seconds and then reapply. Before two minutes have elapsed the temperature of the bath will have fallen to 282° C. (540° F.), at which point it should be kept as steady as possible. When the tung-oil has been in the bath about nine minutes, raise the glass rod at intervals of one-half minute, and when the rod is firmly set note the time. As setting or jellying takes place within a few seconds of fluidity, a good end determination is afforded. Remove the specimen at once, heat the bath again to 293° C., and repeat the experiment with another portion of the sample.

No stirrer is used in the bath. A screen around the bath enables the temperature to be more easily reached. When the cottonseed-oil has become tarry and viscid, it should be renewed; otherwise heating may be irregular.

Iodine Jelly Test.—In a wide-necked 200-cc. Erlenmeyer flask, place 2.5 grams (weight correct to 1 mg.) of the oil. Add 10 cc. of chloroform from a pipette and stopper the flask immediately. Carefully insert a small glass vial into the flask so that the vial stands upright. Into the vial from a pipette run 10 cc. of a solution of iodine in chloroform, containing 0.035 to 0.036 gram of iodine per cubic centimeter. Place the flask in a bath containing water at 25° to 26° C. and allow it to stand there for a few minutes. Keep the flask stoppered, except when it is necessary to remove it to insert the vial and to add the iodine solution. Tilt and rotate the flask so that the vial is upset and the contents of the flask are thoroughly mixed, at the same time starting a stop watch. Keep the flask in the bath at 25° to 26° C. and at the end of every quarter minute tilt the flask towards a horizontal position. Note the time required for the formation of a jelly that does not flow, but sticks to the bottom of the flask or slides as a mass. Record time in minutes and quarters thereof. Pure tung- or Chinese wood-oil should require $2\frac{3}{4}$ to $3\frac{1}{4}$ minutes for the formation of the jelly. If the temperature of the laboratory is more than 2° or 3° C. above or below 25° C., place the flask

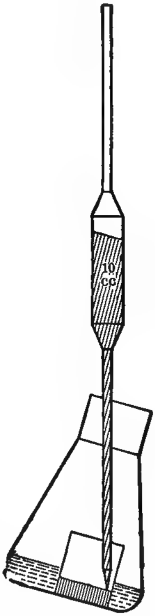


FIG. 1.

containing the iodine solution in the bath and allow it to remain there for several minutes before pipetting out the 10 cc. for the test. The arrangement of the apparatus is shown in Fig. 1.

A convenient procedure for preparing the iodine solution is as follows: Treat an excess of iodine with warm chloroform and after shaking for a few minutes, cool the contents to about 20° C. and filter through glass wool. Pipette 10 cc. of the solution into a flask containing 10 cc. of 10 per cent. potassium-iodide solution and titrate with 0.1 normal sodium-thiosulphate solution. Calculate the iodine content and dilute with chloroform so as to obtain an iodine content of 0.035 to 0.036 gram per cubic centimeter. After dilution, titrate again against the thiosulphate to be sure that the solution is of required strength.

All the details of the above method must be followed exactly.

CHAPTER VII.

LINOLEUM.

By K. G. Mackenzie, M.S.

The manufacture of linoleum, while in a way having quite some similarity to the manufacture and use of paint and protective coatings, is in many respects essentially different. Linoleum is a product used mostly as floor covering, composed of a layer of cork or wood flour, with certain amounts of mineral matter and color, cemented together with linoxyn, and usually fastened and adhering to a burlap base. Distinction should be drawn between true linoleum and the so-called floor oilcloth, which is simply burlap with several coatings of paint. Outside of the fact that the paint must be very resistant to wear and must be applied and dried in a factory, the manufacture of the floor oilcloth may be said to be strictly a paint proposition.

The manufacture of linoleum may be said to be divided into four steps:

(*a*) The manufacture of the cement, which consists, broadly, in partially oxidizing linseed or other drying oils, producing sufficient linoxyn to form a semi-solid product which will soften with heat and will be sufficiently cementitious to hold together the particles of cork, wood flour, etc., in a plastic mass.

(*b*) The incorporation of the cement with the inert matter, which is mainly cork or wood flour or both, with the addition of coloring matter.

(*c*) The application of this mixture to the burlap, giving a soft, plastic sheet.

(*d*) The drying of this sheet in a seasoning room, whereby the drying oil still unoxidized in the cement is converted into linoxyn, and a tough, resistant product is obtained.

Manufacture of the Cement.—The first step in the manufacture of the cement is the partial oxidation of the linseed or other drying oil. The words "other drying oils" have been used since it is possible to substitute a certain percentage of the linseed with drying or semi-drying oils such as China-wood, menhaden, soya bean and corn. Corn-oil, particularly, when used in comparatively small quantities, will give a flexible sheet, which is sometimes desired.

There are two general methods of oxidizing linseed-oil:

1. The so-called scrim process;
2. By blowing.

In the scrim process long sheets of cotton scrim, suspended in special seasoning rooms where the temperature can be carefully regulated, are flooded with linseed-oil, which should preferably be kettle boiled. As soon as the linseed has set to a semi-solid consistency, the flooding is repeated, and this is continued for days and even weeks, until a flexible sheet of partially oxidized linseed-oil is obtained. This is generally yellow to orange in color and quite transparent. It shows a certain amount of elasticity but, on the other hand, can easily be crumbled between the thumb and finger to a pulverulent mass. These sheets are then ground between rolls, either with or without first removing the scrim center, giving a mass which when compressed will cohere to a certain extent.

Blowing.—The blowing of the linseed is conducted along lines similar to the blowing of other fatty oils, either a boiled oil or a raw oil with the addition of dryers being used. With the proper control of temperatures, after blowing twenty-four to thirty-six hours the oil should be brought to such a consistency that on cooling it will have the consistency of a firm, hard jelly, and one may walk upon it.

Manufacture of the Cement.—Cement is now made by mixing the oxidized oil with fossil gums and resin in steam-jacketed cylindrical pans, provided with a large number of stirring-rods. An intimate mix is thus brought about and the ingredients fused to a homogeneous mass, usually dark brown in color. Experienced operators can tell with great accuracy, by the appearance of the mix, just when it is heated enough; and it is then quickly withdrawn, allowed to cool partially, cut up in blocks and after further cooling removed to the mixing room.

Mixing.—In the mixing room the cement, together with the cork and wood flour and coloring matter, is passed through steam-heated mixers, where a product is finally prepared of a coarse, granular nature, the particles of which will cohere under pressure of the hand. This mixture then goes to the calenders or inlaying process. In the calendar the mixture is rolled out to a definite thickness on a burlap sheet, the mixture being forced into the interstices of the burlap, and thus being prefectly keyed to it.

Manufacture of Inlaid Linoleum.—Where an inlaid linoleum is to be made the process is more complicated. An inlaid linoleum is, of course, one having a definite pattern of different colors which extend through to the burlap back. Although there are a number of different processes and methods for the manufacture of inlaid, two methods will be described which are representative. In the first and older method perforated trays are used with openings corresponding to the position of a particular color on the finished sheet. Trays are placed upon the flat burlap sheet and the colors upon the different trays as they are applied pass through their respective openings, and are left on the burlap upon the removal of the tray, very much on the principle by which different colors are applied by stencil. The bottoms of the trays are raised a sufficient height above the burlap so that the layer of linoleum mixture will be of the required thickness after finishing. After all the colors have been applied and the pattern is filled out, the burlap is drawn under a steam heated press where pressure and heat is applied and the pulverulent material is reduced to a composite sheet.

In the other system, which is sometimes known as the Walton Inlaid System, the different colors are prepared in sheets of approximately the width of the finished product. These sheets come down over knifed rolls, which, very much after the order of the old-fashioned pie-crust cutter, cut out pieces of the colored mixture, carrying them around and applying them to the burlap, at the same time discarding the pieces of the particular color representing positions in the finished sheet which are to be occupied by other colors. The effect is somewhat similar to the making of a pattern by fitting together pieces of colored paste-board on a back. After all the colors have been thus automatically filled in, the sheet goes under pressure rolls where the separate color sections are amalgamated into one sheet.

Drying.—The linoleum, as it is prepared now by the calender or the inlaying machine, is still in a soft and plastic condition and must be converted into the tough, resistant product of commerce. This is done by the oxygen of the air assisted by heat, and is one of the most expensive operations of the linoleum industry, since enormous amounts of linoleum must be constantly tied up, representing capital invested, while they are being properly seasoned. The seasoning rooms in which this is done are long, preferably of fireproof material, and heated by steam coils. The linoleum is placed in these seasoning rooms, which are sufficiently wider than the linoleum itself to allow easy passage on either side, either by festooning from the top to the bottom or by laying out in flat sheets on wire beds. Where the flat bed is used the linoleum must be cut in pieces, usually slightly longer than the standard 90-ft. length, and after the seasoning is complete each piece must be drawn separately from the seasoning room. This latter method is to be followed where work is being done with the thicker grades of linoleum, cork carpet, etc.

Printed Linoleum.—A product known as printed linoleum is still sold in large quantities. This is a product along the same lines as floor oilcloth, being a plain colored linoleum with a paint pattern upon it instead of a product with simply a burlap base.

Saturated Felt Oilcloth Floor Covering.—Although not related in any way to linoleum, mention should be made of this new floor covering in which the burlap base is replaced by an asphalt-saturated felt. This has the advantage that a thicker sheet is obtained, better counteracting any slight irregularities in the flooring, which would cause points to be formed with the ordinary floor oilcloth and is, moreover, waterproof and will thus lay flat.

Since its introduction the felt base fabric has largely displaced the old floor oilcloth, but the genuine linoleum as a floor covering still maintains its popularity as a pleasing, well-tried, satisfactory fabric.

CHAPTER VIII.

MANUFACTURE OF VARNISH.

THE manufacture of varnish is carried on at the present time as a definite business, independent of any other, and is in fact subdivided so that the same concern does not make or try to make all kinds of varnish. In fact it is not unusual for some of the smaller and more rarely some of the larger manufacturers to purchase varnishes, either for direct sale or for use in making some special product, from other makers who are particularly successful in certain lines of the work. The greater part of the varnish now used is made from linseed-oil and resins, with turpentine or benzine as dilutent; but most, or probably all, of these makers also make a little shellac varnish, which is a spirit varnish; and they all make damar varnish, which is a solution of damar in spirits of turpentine. On the other hand, they almost never try to make the more unusual spirit varnishes, or those which have nitro-cellulose as a base. Some of the spirit-varnish makers, probably most of them, buy small quantities of oleo-resinous varnishes to add to their compounds, and not a few paint-manufacturers not only buy what varnish they use as an ingredient of their paint, but do a considerable business as varnish-merchants on goods made for them and put up in special packages under their own label and seal.

The writer of this disclaims any special and particular knowledge of what is done by English and European varnish-makers, but in America the varnish-factory equipment may thus be briefly described.

Raw Materials.—The raw materials are resins, oil, and turpentine or benzine. To these may be added the necessary driers, lead and manganese compounds; and, of course, fuel. The oil is almost invariably bought as raw oil, i.e., oil which has no addition of driers and has not been highly heated. This is bought either in barrels of 45 to 52 gallons each, usually called 50-gallon barrels, in which case the buyer pays for the barrel, which he afterward uses to ship varnish in, or in large casks of 200 to 300 gallons, which are the property of the oil-merchant, to whom they are returned. Oil is invariably bought from the manufacturers, as no varnish-maker would feel confidence in oil bought from a middleman, and is usually of especially fine quality, which sells at from one to three cents a gallon above the market price of ordinary pure oil. It is perfectly clear and bright from having been tanked a sufficient time and filtered.

Storage and Treatment of Oil.—When this oil is received, part of it is used just as it is out of the barrels, but the most of that which is to be used for fine varnishes is put through some sort of treatment and then pumped into tanks holding one to three thousand gallons, in a storehouse, where it can be held at a temperature which is regulated by the operator, usually 90° to 110° F., probably never exceeding 120°. This keeps the oil rather thinly fluid, which promotes its settling and clearing. Each varnish-maker has his own secret methods of treating oil, which probably are all about alike. One of the most common is to heat the oil to 500° or 550° for a very short time. This seems to char certain impurities and coloring-matter, which will then settle out. Another is to heat with a very small amount of manganese, or lead oxides, or both: not enough to make the oil dry much more rapidly, but a very little seems to affect the quality of the oil for further use. A comparatively small part of the oil is converted into "boiled oil" of various sorts. The varnish-maker does not make boiled oil for sale, but uses several different kinds in his work. All these oils are tanked for a considerable time, usually several months, before they are considered to be in the best condition for use.

Resins.—The varnish-resins are stored either in the original packages in which they are bought, or in large bins. Usually a considerable quantity of the more common ones is kept in bins, but the less common in the original packages. It is the practice of the varnish-makers to keep a large stock on hand, so as to be able to take advantage of the market. Probably from 10 to 20 per cent. of the entire capital of the business is invested in this way. These resins come from all parts of the tropical and south temperate zones and are not always to be had when wanted. Oil, on the contrary, can be contracted for any length of time ahead.

Spirit of Turpentine.—Nearly all varnish-factories contain one or more tanks of turpentine. This is stored in steel tanks built in the open air and sometimes hold over a hundred thousand gallons of spirit of turpentine. These tanks are closed, except for a vent to admit air when the liquid is being pumped in or out. A few makers have also tanks for benzine, but usually this is bought from day to day and no tank, or only a small one, is necessary. Other supplies are kept in casks, boxes, or small bins.

Packages.—Varnish is sold in barrels, half-barrels, and in tin cans ranging in size from 10-gallon jacketed cans (cased with wood) and 5-gallon cans, both with and without jackets, down to half-pints. All these, except the jacketed cans and the very small ones, are shipped in special boxes holding from 1 to 12 cans of a size, so that considerable space must be allowed for empty packages. When filled, these cans are closed, not with a stopper, but with a piece of sheet brass, stamped to fit the nozzle of the can and made tight by a reamer, a little device worked by hand which makes an absolutely tight closure. In the box with the can is placed a wooden stopper or a metal cap to use after the brass cap has been torn off.

Labels.—The can, of course, is properly labelled. The stock of labels, several different sizes being required for each kind of varnish, frequently amounts in cost to from two to four thousand dollars.

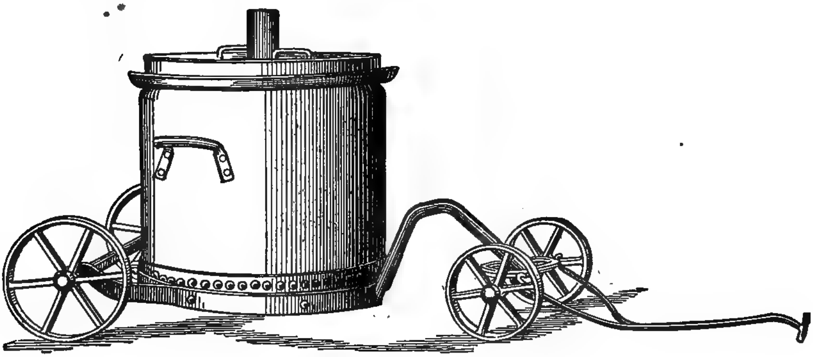
The buildings are heated by steam, which is generated in any suitable boiler. Comparatively little power is used, chiefly

FIREPLACE IN THE OLDEST AMERICAN VARNISH-CHIMNEY.

By the courtesy of Edward Smith & Co.

for pumping and the like, but coke is the fuel used under the varnish-kettles, no other fuel having been found which so well satisfies the requirements.

It was originally the custom to melt the resin in small quantities; in fact the business was formerly a small business, but a good many years ago the American practice was to melt 100 pounds at a time, and this amount was so convenient for computations that it is still accepted as the varnish-maker's unit, but the present general practice is to melt 125 pounds at a time.



VARNISH-KETTLE AND TRUCK.

Varnish-kettle.—For this purpose the kettle (see illustration) is, when new, about 36 inches in height and also in diameter, and weighs when new about 130 pounds. The bottom, which is riveted on, is the part which gives out first. Then the strip containing the rivet-holes is cut off and a new bottom put on, thus decreasing the depth of the kettle. This is repeated from time to time; finally, the whole of the kettle becomes too thin to be safe, and when sold for old copper the weight is sometimes not more than 80 pounds. The fireplace is cleaned out and the material for the fire prepared before leaving at night, or very early in the morning. The fire is started early, and the fire-pit is a glowing mass of coke when the varnish-maker is ready to begin work. The resin has already been put in the clean kettle, which sets on its truck; the loose cover is on, and the kettle is ready to put on the fire, which comes almost, but not quite, in contact with the bottom of the kettle. Through a hole in the cover the varnish-maker inserts a slender iron rod, set in a wooden handle, as Theophilus did about a thousand years ago, and stirs the melting mass of resin.

Melting the Resin.—When all the lumps are gone, and the melted gum, a little of which adheres to the stirring-rod when the operator takes it out for inspection, is quite liquid, the kettle is drawn off the fire. By this time—it is about half an hour from the beginning—from 10 to 25 per cent., by weight, of the resin has been driven off in the form of a pungent, irritating, highly inflammable vapor. To keep this from catching fire the cover is used, and the free escape of the vapor is permitted by the little chimney in the middle of the cover, which so discharges the issuing stream of vapor that the current of air which is rushing up the chimney carries it quickly away from the fire. The escaping vapor causes the melted part of the resin to foam, and if this appears too near the top, the operator draws the kettle away from the fire, unless he can, with his stirring-rod, beat down the foam. It is clearly necessary to have considerable space in the kettle over the resin, and formerly the kettles were made much higher in proportion to their width than now. It is not common to use a thermometer in melting resin because the essential thing is not to reach a certain temperature, but to melt the resin, and this is best told by the feeling of it through the stirring-rod, by the experienced operator. In the laboratory, however, where the lumps of resin are much smaller, the thermometer is necessary. The temperature is seldom below 650° F. when the melting is completed. The temperature and the percentage of loss vary greatly with different resins.

Adding the Oil.—When the resin is all melted and the kettle has been drawn from the fire, and the heat subsided a little, and the foam has gone down, the linseed-oil, which has been made ready in another kettle, is slowly added. The oil is by some, perhaps a majority of makers, previously heated to about 500°, but many use less heat. Some heat only a little above 212° and some not above 100° F. Of course if only a little oil is added its temperature has not much effect on the mass, but it is common to have the oil hot. The amount of oil added is variable, according to the kind of varnish desired. It is commonly measured in United States gallons, which weigh 7¾ pounds, but the varnish-maker is obliged to buy his oil by weight, and a gallon is then said to weigh 7½ pounds. The price is always so much per gallon, but a gallon of linseed-oil, when buying it from the oil-manufacturers, is a conventional, not a standard, gallon, so that the varnish-maker has to buy about 3 per cent. more than he sells. Of course a gallon of hot oil weighs less than a gallon of cold oil, and if it is added hot allowance must be made for that, but usually, if it is hot, it was previously measured cold into the pot in which it was heated.

Cooking the Varnish.—As soon as the oil has been added, which is done gradually, the mixture being constantly stirred, the kettle is put back on the fire. Although the mixture appears to be a complete solution, it is not really so at this stage, for if the mixture, or a drop of it, be allowed to cool, the resinous part will separate, making the drop cloudy; and the common rule is to withdraw the stirring-rod from time to time and let a drop or two of the mixture fall on a piece of glass, where it cools at once and shows by its cloudiness that the combination has not, or by its clearness that it has, taken place. The more approved practice now, however, is to keep a thermometer in the liquid and heat to a certain temperature, previously determined as the best for the particular varnish which is being made, for a certain length of time. This temperature, roughly speaking, is not very far from 500° F., but not unfrequently it is found best to make the heat increase and diminish from time to time, according to a temperature curve which is established for a given mixture. In general it may be said that varnishes containing a large proportion of oil require more cooking than those using a small amount. A 30-gallon varnish, for example, may be cooked six or eight hours, or more, while a 10-gallon one will be done in an hour or two, and where a very small percentage of oil is used the mixture is only heated enough to be sure it will not separate on cooling. One effect of cooking is to make the varnish heavy in body, or, as the English say, "stout"; that is, it increases its viscidity or viscosity, and the longer it is cooked the more turpentine will be required to thin it to the conventional standard of viscosity which is desired in a finished varnish.

Undercooking.—If it is cooked but a little it will take less than the normal amount of turpentine; hence a gallon of such varnish will contain a large proportion of non-volatile matter, and when it is spread on a surface it will dry to a film of more than the usual thickness, and this, in turn, requires more oxygen to dry it, and hence a longer time, than a thinner film.

Overcooking.—Conversely, a varnish which is overcooked takes a large amount of turpentine, a larger percentage of the film evaporates, the film is thinner, and it dries more quickly. Looking at it in another way, since turpentine is less costly than the finished product, the more the varnish is cooked and the more turpentine is added the less is the cost per gallon; but an overcooked varnish is liable to be spoiled by carrying the cooking process too far, and hence the risk makes such a varnish, in the long run, more costly than it otherwise would be. From a standpoint of durability, the varnish which is overcooked leaves a thinner film, which is on that account less durable, than one less cooked; but if it is undercooked the oil and resin are not very thoroughly combined, and the film perishes because its ingredients separate when exposed to the air and sunlight. Since varnishes continually grow darker in color by cooking, the varnishes which are undercooked are paler in color, and on that account fetch a higher price, but obviously are not to be compared in real value and durability with a varnish of the same color made of more costly materials, that is, with carefully bleached oil and pure, clean, pale, hard resins which do not discolor so much in melting, and more thoroughly combined by long and judicious cooking. Most of these considerations apply also to melting the resin. When this is nearly melted and the full heat is on, it darkens rapidly every minute it is kept over the fire; but the undecomposed resin is not soluble in oil, and if the process is not carried far enough the result will be, in extreme cases, that when the oil is added the varnish so made will be a jelly, which must be thrown away; and if the result is not so bad as that, the varnish thus made, while pale in color, will easily suffer decomposition. On the other hand, if the melted resin is heated too long it becomes very dark in color and is less valuable in other respects also. As a rule, when we consider the different grades of a given kind of resin, Kauri for instance, we find that the very pale sorts are a softer resin than the darker pieces. These soft resins take on color more rapidly than the hard ones, hence the tendency is to melt them at a lower temperature, and the resulting varnish, while pale in color, is less durable than that made of the darker resins.

Different Qualities of Resins.—But the cheaper grades, that is, when we get below the normal or standard grade, are dark not only because of the natural color of the resin, but because it contains impurities of various sorts, dirt which, in most cases, settles out and does not injure the varnish much, except in color. Some of these moderately cheap, very dark-colored varnishes are of the most excellent quality in everything but color, and in many cases this is not an objection. For instance, a varnish for mahogany or any such dark wood ought to be dark in color. The dry film is like red-brown glass, perfectly clear and transparent, and imparts a rich effect whose brilliancy cannot be attained in any other way. But if a pale varnish of fine quality is desired, it is necessary to select a pale hard resin and one which discolors as little as possible in melting. These are rare and costly. Some of the finer sorts cost as much as 75 cents per pound. If such a resin does not make a sufficiently pale product, the maker proceeds to pick out the very best pieces from this most valuable resin. It may be necessary to pick over a thousand pounds to get a hundred pounds, enough for one melt, of these select pieces. This hand-picked resin not only costs the original 75 cents a pound, plus the cost of skilled labor for picking over the thousand pounds, but the residuary 900 pounds has by this process been graded down to, let us say, 60-cent resin, a loss of 15 cents a pound on 900 pounds, or $135. If the labor cost $15, the cost of this hundred pounds of resin would be $225, or $2.25 a pound. Clearly, a varnish made of such a resin will be costly. It will, therefore, be used only indoors, that is, for objects not exposed to the weather. Therefore, it will be made with a rather small proportion of oil, and since oil is cheap compared with such a resin, it will have its cost reduced as little as possible in this way. It is impossible to make, even if we could sell, much of this sort of varnish, which must, therefore, have a special small tank for itself, and it will naturally demand the very best and highest-priced labor in the factory at every step of its making and handling until it gets out of the shipping-room.

Very Costly Varnish.—The unavoidable waste in handling a material which is sold in such small quantities is considerable, and it is easily seen that it is quite practicable to make a varnish which is easily worth, from a factory standpoint, at least twenty dollars a gallon and which may be absolutely no better in any respect except color than another made of similar but less costly materials and sold for one-quarter or one-fifth the price. On the other hand, if a man builds a yacht at a cost of half a million dollars and wishes to have in it his wife's boudoir varnished with such a material, the cost does not, and ought not to, stand in the way.

It has been said that there is danger, if the resin is not thoroughly melted and decomposed, or if the mixture of resin and oil is not sufficiently heated for a long enough time, that the same will be spoiled. It should further be said that if the compound of resin and oil be overcooked it is liable to turn to a viscid, insoluble, infusible mass, and this is the more likely to occur if the resin was not in the first place properly melted, and is more likely to take place with varnishes containing little oil than with those which have more. It may be remarked here that varnishes containing little oil are sometimes spoken of as "short" varnishes, and those with a large amount of oil as "long" or sometimes "rich," but the terms "quick" and "slow" refer to the rate of drying and not to the composition.

"Gum."—It is also worthy of note that in all varnish-factories a certain amount—sometimes a pretty large one—of common rosin, or colophony, is used, and this is always called rosin; and partly because of the similarity of this word to resin, partly because from time immemorial all resins have been commercially spoken of as "gums," the word resin is seldom heard in a varnish-factory, all the true varnish-resins being called "gums."

Thinning Down with Turpentine.—When the oil and resin have been properly cooked the kettle is withdrawn from the fire and taken to a sufficient distance, usually into a shed or well-ventilated room, from which it is impossible that the vapors about to be generated should reach the fire and thus cause a conflagration; a quantity of spirit of turpentine, which has been measured out into a special receptacle, is added, being allowed to run in in a small stream, while the attendant vigorously stirs the liquid to promote the solution.

Although the oil and resin compound has previously been allowed to cool somewhat, its temperature is still a little above the boiling-point of the turpentine, and until the whole has been sufficiently cooled by the addition of cold turpentine, part of the latter is converted into vapor and flows over the edge of the kettle in the form of a gas, highly inflammable, and indeed explosive if ignited. If benzine is used instead of turpentine, as it is for making cheap varnishes, this danger is greatly increased, and most varnish fires occur from this cause. Fires do indeed sometimes, but rarely, occur in the chimney where the oil and resin only are used, but these are easily and quickly put out by smothering them, covering the kettle with wet burlap or other wet cloths, a supply of which is constantly on hand. Sooty matter sometimes collects on the bottom of the kettle, and in this sparks of fire are preserved for a considerable time, and the attendant should most carefully see that no such thing is allowed to cause a fire, which is not only destructive to the part of the factory where it is, but is also exceedingly dangerous to the workman who is stirring in the turpentine or benzine. Fires are avoidable if proper care is taken. In a factory with which the writer was connected a fire of this sort occurred many years ago, when benzine was first introduced and before it was known that it was more dangerous than turpentine; but that one fire is the only serious one in this factory in eighty-five years. The most common cause of varnish fires is that the thinning-down shed is not far enough away or not perfectly separated from the fireplace where the varnish is made. When making cheap rosin varnishes, moreover, it is common practice to make a batch of varnish, get it thinned down and pumped out of the kettle all within an hour, and sometimes considerably within the hour. Such haste, so different from the more dignified and deliberate proceedings which distinguish the making of high-class goods, is a contributory cause of much importance.

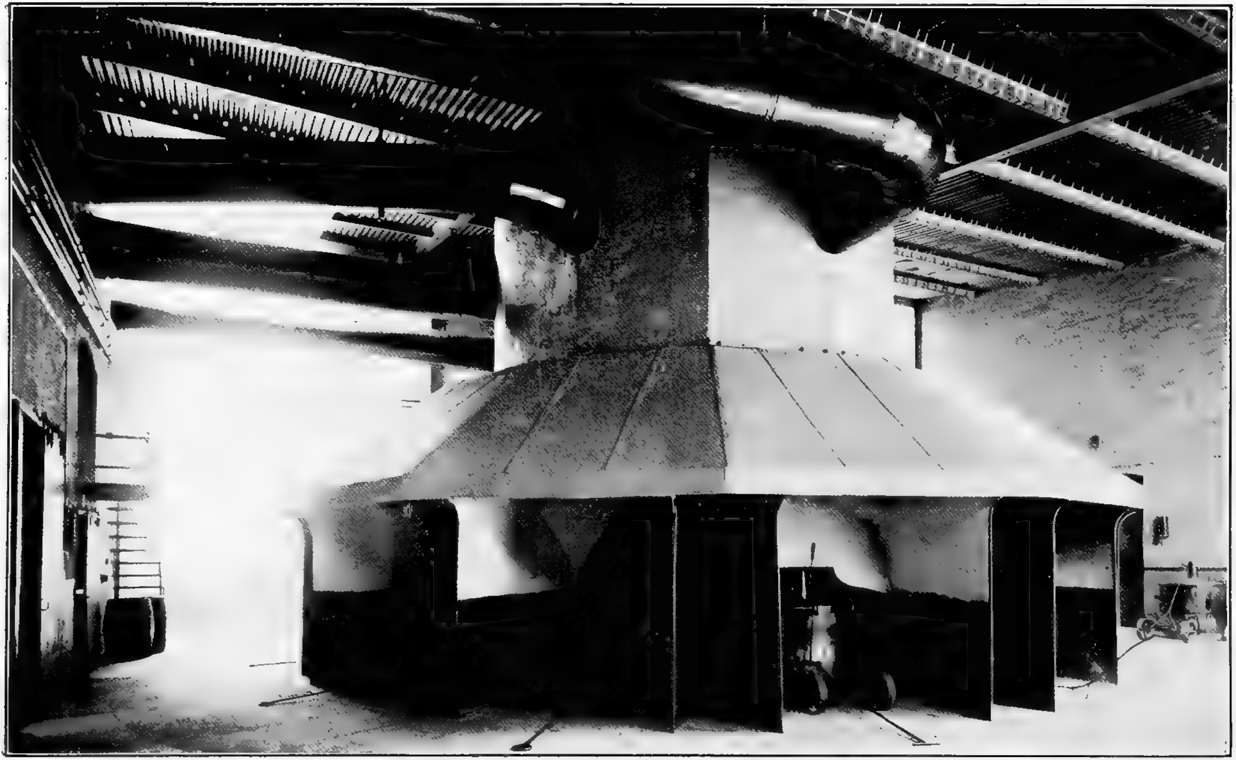
If the varnish is one containing a large proportion of linseed-oil, the compound of oil and resin will be much more fluid than if a small amount of oil is used, and consequently a smaller proportion of turpentine will be needed than is used with the more viscid compound containing a small proportion of oil. Of course it is possible to overcook a "long" varnish so as to make it take more than its normal percentage of turpentine, but since this is rarely done we have some indication of the proportion of resin and oil when we determine the percentage of turpentine, or rather of volatile liquid corresponding to turpentine, which fortunately may be easily done. Varnishes made with 8 gallons of oil to 100 pounds of resin have about 25 gallons of turpentine added, those containing 30 gallons of oil have about 32 of turpentine, and intermediate ones are somewhat in proportion.

Turpentine Better than Benzine.—The question will naturally arise, is turpentine, which costs three to five times as much as benzine, any better than the latter? In most cases it is, for several reasons. One of these is that it is much less rapidly evaporated. There is much more attraction between the oleo-resinous compound and turpentine than between it and benzine, and for that reason turpentine goes off more slowly, and benzine dissolves in the air by diffusion far more rapidly than turpentine, and this has a like effect. It is desirable to have the volatile ingredient of varnish pass off somewhat slowly, especially at first, for when the varnish is spread with a brush it is impossible to avoid putting it on with slight irregularity, and the brush-marks thus made will disappear if the varnish retains its liquid condition for some time, as is the case if turpentine is the solvent. The little ridges of liquid varnish flow out and level up the hollows and the whole surface becomes smooth. Such varnish is said to have good flowing quality. If made with benzine, the latter evaporates almost at once and the varnish takes its initial set before the ridges have disappeared; the surface then dries with these imperfections, and the finished surface shows these brush-marks. These may be seen in any furniture-store on low-priced furniture. Good flowing quality is also helped by other things; the composition, method of manufacture, and age of the varnish have their influence, but the presence of either turpentine or benzine is the most important single factor.

Oxidation of Turpentine.—Another peculiarity of turpentine is that it never completely evaporates. A small portion of it remains behind as an elastic resinous substance, which is considered a desirable ingredient in varnish. Benzine evaporates completely. This thickening of turpentine is due to a process of oxidation, and there is no doubt in the mind of the writer that turpentine has some effect as a drier, acting as lead and manganese compounds do, by passing oxygen on from the air to the oleo-resinous compound. It is possible that a turpentine varnish dries through more quickly than a similar varnish made with benzine, notwithstanding the slow setting of the former.

Factory Nomenclature.—If 10 gallons of oil is added to the melted mass, weighing, let us say, 95 pounds, which results from melting 125 pounds of resin, the resulting varnish is said to be an 8-gallon varnish, because it contains 8 gallons of oil to every 100 pounds of resin originally taken. Similarly, 25 gallons of oil would make a 20-gallon varnish, and so on, the varnishes being designated by the proportion of oil to the hundred pounds of unmelted resin, and nothing is said about the turpentine which is, to some extent, a variable quantity. Of course this is purely a factory nomenclature. The purchaser knows the varnishes he buys by certain descriptive or trade names, and, as in every other business, a name which takes the public fancy is very valuable. Further, the varnish as it comes out of the kettle is not usually of the same composition as any varnish sold, because, in order to get certain qualities, it is necessary to mix varnishes made in different ways and of different resins. It will be obvious that if the maker has, for example, three tanks of 10-gallon varnishes, made respectively of Zanzibar, Kauri, and Manila resin, and also three tanks of 30-gallon varnishes made from the same resins, he is in a position to supply nine different kinds of 20-gallon varnish, each differing from the others in certain properties peculiar to each mixture, and also in price, making each of these mixtures from two tanks, and an indefinite number by mixing them in a more intricate manner.

Art of Mixing Varnishes.—It would be indeed remarkable if some of these 20-gallon mixtures were not better for some special purpose, or even for general use, than any possible 20-gallon varnish, made from a single resin, just as it comes from the kettle. It will also be obvious that an indefinite number of 12-, 15-, 18-, 22-, 25-, and 28-gallon varnishes may be made from these same tanks, and if, in addition, the manufacturer has a set of tanks of 8-, 16-, and 20-gallon varnishes, each set representing, say, these same three resins, the number of possible combinations passes imagination. It is to be further remembered that varnishes are made with as little as 3 gallons of oil and as high as 60; that the more important resins are sold in from two to ten grades, and that the number of these resins is very great and is constantly increasing. It will be seen that a knowledge of the qualities of the various varnishes, and especially of their effect in mixtures, is of as much importance as knowing how to manipulate the materials in the kettle, and the expert, to be an expert, must be intimately and practically acquainted with the use to which the varnish is to be put and the way in which it is necessary to apply it, and how



MELTING-ROOM OF MURPHY VARNISH COMPANY AT CHICAGO.

By the courtesy of the Murphy Varnish Company.

these uses and conditions vary. He should, therefore, have as the simplest foundation a good working knowledge of the furniture trade, of wagon and carriage building, of railway engines and coaches, of ship and boat construction, and of house painting and decoration. To these he may add the lesser trades and specialties, from the making of oilcloth to the japanning of hooks and eyes, as far as his natural abilities and acquired opportunities may allow.

In view of all the foregoing facts, the proposition that the art of varnish-making offers an opportunity for the continual activity of an ingenious and receptive mind, for an indefinite period, is confidently submitted to the acute perceptions of the candid reader.

From a pamphlet recently published by The Murphy Varnish Company, the following maxims and definitions are quoted, by permission. They are not in the original order, and a few verbal changes are incidental to rearrangement; but they are not essentially changed, and they are full of knowledge and wisdom, the fruit of experience. Their value is increased by the source from which they come:

There are three enemies to fine varnish:

The man who thinks all varnishes are necessary evils.
The man who thinks any varnish will do.
The man who does not think about varnish at all.

When you talk with the painter about your finishing job or with the architect about his finishing specifications, or with the manufacturer or salesman of whom you buy varnished things, some knowledge of varnish will be useful.

These men are in the habit of dealing with people whose minds are blanks on the entire varnish problem. They will treat you with more consideration when they see that you really know something about the business.

Why Varnish is Used.

To Preserve Wood and Its Beauty.—To varnish wood is the only way to preserve its beauty. It preserves the beauty in just so far as it preserves and protects the wood itself. Paint will preserve and protect the wood; but it hides the beauty.

A freshly cut piece of wood looks new and bright, and shows the grain clearly. In a little while it turns dull, and the grain pattern is blurred—oxidation of the atmosphere is rotting its delicate fibres. If left outdoors it turns black, and all trace of grain is lost—the exposed fibres have been entirely destroyed.

Transparent Preservative.—Varnishing fills the pores of the wood and seals them up and makes the surface damp proof—itself practically invisible. Unless the varnish cracks and lets in moisture and air, the wood is preserved as in an air-tight glass case and oxidation postponed. The important thing is to get varnish that does not crack.

To Increase the Beauty of Wood.—A freshly cut piece of wood looks brighter and shows the grain pattern more clearly, for a moment, when you wet it; though the wetting will soon make it dull. Varnishing makes that momentary brilliance permanent. As a photographer would say, it "develops" and "fixes" the subtler tracings of the grain and its finer tints.

To Preserve Metals and Colors.—Varnishing preserves metals from rust and other materials from various kinds of destruction, as it preserves wood from decay; and it is widely used with this very practical and prosaic purpose. It excludes the air and dampness, hence the protection. It is used also to protect stains and colors, which are not of themselves waterproof.

To Confer Its Own Beauty.—The polish on a fine piano o door, panel or mantlepiece, is itself an elegance. Dead finishe and eggshell finishes have their own artistic values of toning an richness.

Where Varnish is Used.

Almost Everywhere.—On the carriage and coach and wagon on the railway car and street car and motor car; on the steamshi and steamboat and motorboat and yacht and canoe; on the piano and organ and all other musical instruments; on all the natural woodwork of buildings, inside and outside; on every article of natural wood furniture; on the sewing-machine and the typewriter and art metal work, and all kinds of machinery and implements and tools; on many kinds of leather and paper and stone work; on oilcloth and linoleum and the iron and tin things in your kitchen, down to the labels on your fruit cans and the stoppers in your bottles.

Everybody Pays for Varnish.—With the exceptions of food and clothing perhaps nothing else is so universally paid for. People generally do not select it; and as a rule do not get a good article; but it is charged up with a good round price.

How You Can Get the Worth of Your Money.—You are always paying for varnishes that check and crack and bloom and blur and disintegrate and crumble and spoil the beauty of your varnished things. Why? Merely because you have never taken one hour to learn a few plain facts about varnish and varnishing.

You may just as well have the varnishes that last three or four times as long and keep your things new and beautiful. It will cost no more.

A Different Varnish for Every Purpose.

"*All Varnishes Look Alike.*"—Because they *look* alike, people suppose they *are* alike; and that any varnish, put on anyhow, will *do* for any job. Varnish is varnish: yes, and medicine is medicine. You can go into a pharmacy where a hundred different medicines, the cures for a hundred diseases, all look alike—a hundred bottles of white pellets; take a few of them, and if you're still alive you'll know the difference.

Two Hundred Varnishes for Two Hundred Uses.—A few more than two hundred are made by Murphy Varnish Company. They all look very much alike; but each one is a problem by itself; fitted to accomplish a separate and exact result, as each white pellet is to cure a certain disease. Their prices range from

$1.25 to $6.00 a gallon, but the most expensive would not do certain kinds of work for which less costly grades are devised.

A Worthy Gentleman's Mistake.—He thought all varnishes were for all uses, and that getting the best was simply paying the most. He could not find marine varnish that cost more than $4.00 a gallon; so, he paid $5.25 for piano varnish, and put it on his motor boat. Of course it went to pieces in a month, though it lasts twenty years or more on a piano. Piano varnish is not an outdoor varnish; especially, it is not a salt-water varnish.

"Best" Varnish.—There is *best* varnish only in the sense that there is best *cloth*. It depends on what you want the cloth for: business suit, hunting suit, or dress suit—August or January. It depends as completely on what you want the varnish for.

Sixteen Classes.

Varnishes, according to their uses, may be grouped in the following classes:

1. *Architectural varnishes*, for doors and floors and all other trim, both inside and outside the building: and for special decorative work.

2. *Baking varnishes*, for art metal work, grilles, partitions, etc., for sewing-machines and typewriters and fine machinery.

3. *Black varnishes*, for general iron work, machinery, implements, utensils, etc.

4. *Cabinet varnishes*, for cases, files, desks, fine tables and chairs, and for all the more elegant pieces of home and office furniture.

5. *Carriage varnishes*, for carriages, buggies, coaches, etc., for bodies and for gears.

6. *Casket varnishes*, for caskets and casket cases of various kinds.

"Coach Varnishes."—"Coach" is the most abused and the most confusing word in the business. Originally "coach varnish" meant a varnish for coaches, but the name has come to be applied almost universally to varnishes for house use, especially to furniture varnishes—to some very poor furniture varnishes.

7. *Furniture varnishes,* of many kinds and grades, for many kinds and grades of furniture.

8. *Implement varnishes,* for all sorts of agricultural implements.

9. *Leather varnish,* for carriage and motor car tops.

10. *Lineolum varnish,* for linoleum and oilcloth.

11. *Marine varnishes,* for steamships and steamboats and motor boats and yachts and canoes—for all craft; inside and outside work.

12. *Motor car varnishes,* for motor cars of all grades; for wood and for metal bodies, and for gears; for natural wood or over colors.

13. *Piano varnishes,* for pianos and organs in natural wood or color; for their plain surfaces and for their legs and mouldings. Sounding-boards require a special kind.

14. *Railway varnishes,* for palace and passenger and baggage cars, and for street cars—for all sorts of cars that are made of wood—inside and outside work—for floors and decorations and lettering.

15. *Steel car varnishes,* for all kinds of cars that are made of steel, and for all parts of them; for locomotives and tanks.

16. *Wagon varnishes,* for delivery wagons, hospital wagons, farm wagons, trucks, etc.

Seven Hundred and Fifty Coats to the Inch—Must be Very Fine.—It requires from six hundred to nine hundred coats of varnish to build up a surface an inch thick; three or four coats are only as thick as a sheet of good writing paper. Plaster of that filminess would have no wearing quality at all. Varnish will have little, unless it has the best oil and gum, and unless it is made with scientific exactness.

There is no substitution of frail and coarse ingredients, and there are no quick and easy methods, in making the varnish that *lasts.*

Varnishes do not wear simply because they are heavy. Horse-blankets are heavy, but a cashmere shawl outwears many of them.

Filtering.—One of the most important things in making fine varnishes is to get the dregs all filtered out of it. There are cheap methods of half filtering—perhaps all that can be afforded for bargain-counter varnishes.

Perfect filtering is an expensive process.

Ripening.—Perfect ripening is required to complete the purification begun by filtering. Low-price varnishes are hurried from kettle to customer, as green as green apples and as full of trouble.

Fine varnishes are tanked for twelve months or eighteen or twenty-four, as the character of each may require, until they are perfectly cured; ripe and clear and pure and rich as twenty-year port. The tanks are of steel, and they stand in rows in vast storehouses which are kept at an even temperature all the year round.

The Varnish Room is the Manufacturer's Bogey.—The name of Varnish-room Troubles is Legion. Some of them are due to irregular heating, to coal gas, to careless ventilation, to drafts and dampness caused by the poor construction of the room itself. For such troubles the varnish-maker cannot be held justly responsible, though he is often unjustly blamed when the varnish "goes wrong" under these conditions.

Your Need of Uniform Varnishes.—In a great finishing room where schedules are fixed and work is rushed, it is all-important that a varnish be uniform.

Hardeness vs. Toughness.—These two qualities are desirable in most varnishes, but it used to be supposed that a hard varnish could not be tough, any more than a sour apple could be sweet. But the patient experimenting year after year has made it possible to combine these opposite qualities to a considerable degree.

Quick-drying vs. Durable.—There is an eager and almost universal demand for varnishes that dry quickly; but the rule is that varnish-makers take months out of the endurance for every hour that is taken from the drying-time.

Elastic vs. Fine Polishing.—Elasticity is one of the essentials in many of the finest varnishes; but the cheap and easy way to make it elastic is to make it soft and sticky. The ice-like varnish, with no more stretch or yield than ice, is easy to polish.

Elastic varnishes with no tack, firm and solid and beautiful, mark the highest reach of varnish-making for interior varnishes.

Easy-working vs. Full-bodied.—Of course, a thin, watery varnish works easily; but it looks thin on the job. It means one or two extra coats. It is easy to make a full rich varnish—which pulls and drags and tires the painter out.

Troubles with Low-price Varnishes.—Low-price varnishes, that are full bodied, pull and drag and streak and lump—much has to be sandpapered off. Low-price varnishes that work easily, because they are thin and watery, require an extra coat or two for a decent-looking job.

What it Means to Save Ten or Twelve Dollars.—Of course you can get a kind of finish for a ten- or twelve-room house on which you save ten or twelve dollars. But it means a cheap-looking finish, to begin with.

It means a dried-out, cracked, shabby-looking finish in a little while.

It means that your fine woods are not artistic, and that your pride in the home is turned to vexation.

It means that you must shortly refinish; and that the refinishing, labor and all, will cost several times the ten or twelve dollars you have saved—to say nothing of the bother.

Above all things, do not allow yourself to be won over by anybody's advice to use a varnish because it *dries quicker* and allows you the use of the room a day or two sooner.

The varnish that dries most quickly is the varnish that gives the poorest service.

Economy.

Using a strictly first-class interior varnish, costing, say, $3.00 a gallon will cover, on an average, 650 sq. ft., first coat.

Second coat, 850 sq. ft.

Third coat, 850 sq. ft.

A total for the three coats of 2350 sq. ft., or an average for each gallon of 783 sq. ft.

An inferior varnish spreads over less surface, because it is made of greater viscosity, since it is necessary to have a thicker film to get the required gloss and to have fair wearing quality. Hence we have the following figures:

Average covering power of varnish sold at $1.50 per gallon:

First coat, 450 sq. ft.

Second coat, 600 sq. ft.

Third coat, 600 sq. ft.

A total of 1650 sq. ft., or an average for each gallon of 550 sq. ft., making a difference in average covering power in favor of the $3.00 varnish, as compared with lower-priced grades, of 233 sq. ft. per gallon, or 42 per cent.

The following estimate of painters' wages is the amount paid the journeyman, plus the master painter's loading to cover his expenses and profit. In some cities the total is considerably larger.

A painter will spread, on an average, about 1 gallon of varnish per day whether low or high priced; covering with the $3.00 varnish, 783 sq. ft. per day, or with lower price competing grades 553 sq. ft. per day, a further saving of 42 per cent. in time.

Owing to the better quality of the $3.00 varnish, a workman can rub at least 20 per cent. more surface in a given time, which with wages at 40 cents per hour makes a saving of 64 cents per day of eight hours in that class of work.

One gallon of fine varnish at $3.00 per gallon costs as much as 2 gallons of $1.50 varnish, or 100 per cent. more. Take two houses exactly alike in their varnish requirements. One of them is finished with 10 gallons of varnish at $3.00 per gallon, amounting to $30.00. To put on this 10 gallons of varnish requires the labor of ten days at, say, $3.20 per day, or $32.00; a total of $62.00 for the work, if left in gloss finish.

In the second house is used varnish costing $1.50 per gallon. We have taken $1.50 as a minimum price for a house varnish because with a grade at a lower price satisfactory results are seldom obtained and are lacking in permanency. To cover the same amount of surface with the $1.50 goods requires 42 per cent. more material or 14⅕ gallons, costing $21.30. To put this varnish on takes fourteen days' labor at $3.20, amounting to $44.80, a total for varnish and labor of $66.10 for work left in the gloss, a difference in favor of the house done with the $3.00 varnish of $4.10. If the last coat in these houses is to be rubbed there would be at least a saving of $5.00 in labor on the house finished with the fine varnish, making a total saving for rubbed work of $9.10.

As to Wax in Varnish.

Wax Put into an Interior Varnish Injures It.—Wax does give a beautiful dead finish to a fine gloss varnish without the labor of rubbing; but the dull, rich look lasts only a few weeks, as the finish changes back to a gloss.

Wax does give to poor varnish—for a little while—a rich and velvety appearance. The charm of it lasts just about long enough for the contractor to get his pay. Then the owner finds that he has been stung: because the wax is a soft material and has softened the varnish up to the extent of its use.

If wax did give a permanently rich look it would revolutionize varnish-making, for it is about the cheapest thing that can be put into varnish—and that's why it is put in—also to save labor of rubbing.

Varnish Definitions and Explanations.

Varnishing or Finishing.—Varnishing is not simply to put on varnish, but also to put on all the other materials which may be needed to make a foundation for the varnish; or which may be desired to give special effects in color or tone. Finishing, as it refers to the labor, means varnishing, or enamelling, or painting.

The Finishing Coat.—A phrase commonly used by painters to denote the final coat of varnish or other material with which a job is completed—the last thing put on.

Number of Materials and Coats. A coat is one spreading of any material. Sometimes but one or two materials are used;

usually, three or four; occasionally, five or six. Excepting varnishes and enamels, but one coat of a given material is commonly put on: but that is a rule with various exceptions. From two to seven coats of varnish or enamel are put on. Three coats of varnish is the average: but the best piano-makers put on six or seven.

Priming Coat.—A primer is whatever material may be used to fill the pores of the wood and prepare the surface. Fillers, sealers, shellacs, and certain stains are the principal primers.

Rubbing Varnishes.—Distinguished from finishing varnishes. They are hard drying and are used on cars, automobiles, carriages, coaches, etc., to build up a firm and very smooth surface for the finishing varnish.

Sandpapering and Final Rubbing.—When a coat is dry the painter rubs it to an ideal smoothness with a soft wet felt which is dipped in pumice powder—sometimes with fine, wet, block pumice. Undercoats are sometimes sandpapered to scratch the gloss and give succeeding coats a better grip.

The final coat on furniture, piano or house work is often rubbed with pumice and water, or with oil, or polished with the palm of the hand.

Finish—Two Meanings.—A finish is the entire coating which is built up of all the materials. The finish, also, is the look of the final coat; gloss, semi-gloss, polish, eggshell, dead, etc., produced by the character of the finishing coat itself or by some special kind of rubbing.

Dead Finish.—That expression is an absurdity; for when a varnish looks dead it has lost all semblance of finish; but the expression is here to stay, and we must understand it. Dead finish does not mean dead varnish, or varnish that looks dead. It means that a varnish has been rubbed from the gloss to a subdued and rich effect—given a soft toning which is both artistic and popular.

Gloss Finish.—Means that the final coat will dry to the desired effect, and is to be left in the gloss—not rubbed in any way.

Light.—The use of the word "light," in the varnish world, is quite confusing: sometimes it means the opposite of dark, and sometimes the opposite of heavy. In this book, whether we refer to varnish, color, copal, stain, filler, or any other finishing material, or to wood, we use the word in its color sense, as the opposite of dark. To convey the other meaning we say "light-bodied."

Pale, Palest.—These words mean that a varnish is very light, or almost colorless. It depends on the copal and the oil and the process.

Body—Two Meanings.—In the *description* of a varnish it means weight, fulness, substance. In the *name* of a varnish it refers to the body as distinguished from the gear of a vehicle. "Palest Durable Body" is an almost colorless, durable varnish for the body of a carriage.

Flowing Varnishes.—Varnishes intended to be left in the gloss. A good flowing varnish will keep on spreading itself until it is perfectly even all over the surface. Varnishers become expert at "flowing." Don't try it yourself.

Fine.—The word fine, as applied to finishing materials, does not mean thin or delicate. Varnishes of lightest weight or heaviest body, those which are most free-flowing and those which have viscosity like molasses in January, may be equally fine. Fine means that a finishing material is made of pure and high-grade ingredients, and that it is made with scientific precision.

Tack.—All varnishes before they become quite dry are sticky. That is called tack. The vital question is whether they will be tacky after drying.

Blooming and Blurring.—Blurring is to show dirty-looking streaks or spots. Blooming is a cloudy, bluish, film-like appearance on the varnish. These troubles come, sometimes, because the varnish is made of poor material, but in wet weather these troubles may appear on the best possible finish, particularly of a carriage or motor car. The trouble is usually corrected by washing with cold water and standing in the sun.

Sinking in or Deadening.—If the pores of open-grain wood are not properly filled, they suck the oil out of varnish, which then loses its life-look in a little while—looks dead and sunken—is dead, and soon crumbles. Sinking in is also caused by glue working through a thin veneer. In one case a fine varnish is ruined by a poor filler—in the other case by saving in cost of veneer.

Checking, Cracking, Crumbling.—Those tiny cracks (examine your piano), are checks. Those larger and longer checks (look at the floor), are cracks. When the cracks deepen and widen until particles of varnish stand out like bits of bark (look at the front door), it is crumbled—dead.

Disintegration.—This is what has happened. The varnish film has become oxidized and therefore disintegrated. (Note the appearance of a charred stick of wood taken from your fireplace.) If the ingredients are of good quality, oxidation will take place more slowly. If of poor quality, or if an inside varnish is used for outside service, oxidation will take place quickly.

The Trim.—The trim is all the woodwork which is built into a room—doors, floors, mantles, wainscot, casings, etc.

Painter and Painting.—A man who does varnishing is sometimes called a painter. Varnishing grew out of the older craft of painting. Varnishing itself is often spoken of as painting. It is almost universal to say that carriages, automobiles and cars are repainted, when they are revarnished.

Woods of Different Structure.—Everybody knows, in a general way, the difference between hard and soft woods; but the difference in grain-structure is quite as important to the painter and the varnish-maker.

All woods are porous. These having small pores are called close-grain. Those having large pores, open-grain. Some hard woods and some soft woods are close-grain; some are open-grain. It is with open-grain woods, hard and soft, that special care must be taken to get good finishes.

Use of Soft Woods.—It is a peculiar mistake to suppose that only hard woods are commonly varnished. Many of the most artistic effects in modern homes and offices are secured by the use of Murphy stains and varnishes on soft woods—in some cases even on open-grain soft woods.

Natural Woods.—A house trimmed with "natural woods" has varnished woods, as distinguished from painted woods. Natural simply means to show the grain.

How to Care for Varnished Things.

Don't Clean Varnish to Death.—No varnish will endure being scrubbed with a brush or with hot water. It is not iron or tile or leather.

No varnish will endure the chemical action of ammonia or Pearline or any kind of lye soap or any of the common washing-fluids or washing-powders.

No varnish will endure having dust or mud rubbed off, or wiped off, or will endure having the grits of dust and mud driven into it by the water-blast from a high-pressure hose, such as carriages and motor cars are subjected to.

Cleaning a Carriage or Motor Car.—Mud, wet or dry, should be removed with flowing water, squeezed from a clean sponge, or flowing from a hose with very gentle pressure—not with a water-blast.

There is no surer or quicker way to ruin the finish than ordinary public-garage or livery cleaning.

The Use of Soap.—The less soap the better. On a carriage there is no need of using it at all. On a motor car it should be used only where oil is spattered. If there is much spattering of oil you need a new chauffeur. Unless the bearings are flooded for a race, a greasy car is due to ignorance or carelessness. However, what grease there is may be washed off with soap. Use a good, pure carriage-cleaning soap—and that only where necessary.

The thick and solid grease spots may be removed by waste that is *dampened* with benzine or naphtha.

The Proper Garage or Carriage House.—The ideal garage or carriage house is concrete. If this is not convenient, then have it warmly built, and keep out drafts. When not in use the carriage or motor car should be covered with a white muslin cover, and the cover should preserve its whiteness.

Do not stand the motor car or carriage in the stable, or near the horses—ammonia fumes are deadly to varnish.

The Care of a Piano.—Dust the piano lightly, with a fine silk cloth—not with a feather duster. Wash it, once a year, with a moist chamois; the water at 60° F. or lower. If soap must be used let it be pure castile.

Once in four or five years have a first-class cabinet finisher come in and give it a thorough cleaning and polishing.

All dust contains grit and all smoke contains acid. When not in use keep the piano covered, and see that the cover has a soft clean lining.

Avoid Sudden Changes of Temperature.—However well the varnish has endured weather testing, it may be seriously affected by instant extremes of temperature.

A glass dish may be filled with boiling water (slowly) without cracking it; and may be filled with ice water (slowly) without cracking it; but you must not plunge it instantly from boiling into ice water.

Don't open opposite windows of a warm room so that an icy wind blows on the piano.

Don't allow servants or children or curious people to lay their hands on the piano or carriage or motor car—it creates the instant change of temperature.

If a piano is delivered during cold weather let it remain in the box two or three hours and warm up *gradually* to the temperature of the room before unboxing.

The Care of Varnished Floors.—Don't scrub them. Don't sweep them. Dust them, and wipe them off with a damp cloth—using cool water. When very dirty use a cool suds of pure castile soap.

When the varnish begins to show the effects of hard wear, sandpaper it lightly and put on a new coat. A coat in time saves nine-tenths of the expense, and keeps your floors in elegant condition.

The Care of Furniture and Standing Work.—Dust it lightly, with a soft cloth. When washing is needed use cool water and castile soap.

When it begins to look dingy, call in a good cabinet polisher. Any furniture polish you are apt to get will hurt fine varnishing. Sometimes the harm does not appear until long after.

Don't suppose that any varnish can last forever. Low-price varnish cannot last long enough to make the time worth mention, however you care for it. Fine varnish lasts a reasonable time, even with careless treatment—lasts two or three times as long if you treat it well.

Endurance is Economy.—Many things, such as front doors and vestibules and porches, floors and stairs, linoleum and oilcloth and certain kinds of furniture, carriages and coaches and motor cars, yachts and motor boats and steamships, railway and street cars, must have periodical revarnishing.

Extra revarnishings are a squandering of money—not simply for the finishing materials, but for the labor. The labor costs more than the materials. Often five times as much.

CHAPTER IX.

TUNG-OIL.

Tung-oil, or Chinese wood-oil, is a remarkable oil which surpasses linseed in its rapidity of drying; it is obtained from the seeds of a tree known to botanists as the *Aleurites cordata*, much resembling the ornamental tree known to us as *Paulownia japonica;* the seeds resemble chestnuts and contain somewhat more than half their weight of oil, about four-fifths of which oil is obtained by grinding the seeds and pressing, very much as linseed and other vegetable oils are made. The nut is said to be poisonous if eaten; but it is not reported that the oil is so. The oil has a peculiar odor, resembling that of rancid grease obtained from bacon; it is yellow in color, darker than linseed, and is, when fresh, turbid; this turbid oil is said to dry better than it does after it has been cleared. When spread on glass (or other non-absorbent surface) it dries "flat," that is, with a rough surface, not glossy, and makes an opaque white film. Linseed-oil, after it has taken its initial set, dries from the outer surface; but it is commonly said that tung-oil dries throughout at the same rate. As the oxygen is derived from the surface, this statement is no doubt only approximately true; but it dries more rapidly and uniformly than linseed.

The next most remarkable quality of tung-oil is that if it is heated to about 400° F. it coagulates; it does not break like linseed, but apparently the whole mass of the oil is converted into a polymeric modification, and is a jelly, insoluble in all the ordinary solvents; on this account great care must be taken in heating it. It may sometimes be heated to about 500° F. for a few minutes; but prolonged heating to 400° F. is likely to cause it to coagulate into a gelatinous solid free from a greasy feeling.

Tung-oil seems to be rather more repellent to water than linseed; but the writer has had very little practical experience with it; the varnishes made with it have not seemed to be as reliable as those made with linseed-oil; they are liable to undergo a decomposition while standing in the tank or can, in many cases.

There is a considerable amount of this oil used in the United States; the most of it seems to be purchased by makers of rosin varnishes, some of whom must have successful methods of using it. It is more costly than linseed.

Its specific gravity averages about .938, varying from .936 to .944; its saponification number is about 192.5, varying from 191 to 197; its iodine number is 160, varying from 155 to 165.

It is said by some authorities that the gelatinization of this oil by heat is accompanied by a large absorption of oxygen; by others that it is not so, but is a polymeric change. The latter seems the more likely.

It derives its name of wood-oil from the fact that it is used as a protective coating for wood in China, being used as a sort of varnish. It combines readily with lead and manganese oxides to form driers, and a certain proportion of lead in combination is said to make the film glossy and transparent instead of flat and opaque.

The use of tung-oil has greatly increased since a method of treating it has become generally known. In its natural condition it is of little use; but if it is converted into a lithographic oil or stand-oil it is entirely different in its behavior. This treatment consists, in its simplest form, in heating it to about 420° F. for two hours or a little more; great care must be taken to prevent local overheating, which causes polymerization, the oil changing into jelly, quite useless. It is much easier to heat it in a mixture with other oil, as linseed, or with rosin, either of which prevents jellying. Practically the whole of it is used in varnishes, and probably nine-tenths of it in rosin varnishes. Some makers add a proportion, usually not more than an equal amount, of linseed-oil and heat the mixture until sufficient cooking has been done; this compound oil is then used in varnish-making, either with prepared rosin or with some of the standard varnish resins. It is very successfully used with what is called "ester-gum," which is made by combining glycerine with rosin. It is very generally known that animal and vegetable oil are compounds of fatty acids, such as oleic acid or linoleic acid with glyceryl, which is the basic radical of glycerine; such a compound is called an ester, a kind of an organic salt. Rosin is an acid substance, and if we combine glyceryl with the rosin acid we get a rosin ester, which differs from an oil in having a rosin acid in it instead of a fatty acid. That is what we mean by an "ester-gum." This kind of a rosin preparation makes a better varnish, especially with tung-oil, than limed rosin. A great objection to rosin as a varnish material is that it is soft and viscous substance, appearing to be a solid but having a capacity of flowing slowly; and when dissolved in oil it retains its viscous and sticky nature; but tung-oil, when prepared as has been described, dries more rapidly and especially dries harder than linseed, and overcomes this property of rosin; so that these varnishes are more generally useful than the old sort of rosin varnishes, and displace, because of their cheapness, the varnishes made of true varnish resins.

It will be obvious that such varnishes may be mixed with oleo-resinous varnishes, and also that resins like Kauri or Manila may be melted in the ordinary way and compounded into varnish with a prepared tung-oil or linseed- and tung-oil mixture; and such a varnish will dry more rapidly and harder than a pure linseed-oil varnish.

These tung-oil varnishes are repellent to water in a remarkable degree, especially when fresh. It is the belief of the writer, which is shared by several of the best varnish-makers in this country (but not by all), that these tung-oil varnishes are less durable than the oleo-resinous varnishes of the older type which they have largely displaced. Their hardness, brilliancy and remarkably quick-drying qualities ensure their general use; but where extreme durability is absolutely required, or where the finished surface is to be revarnished when it becomes dull, their use may not prove to be economical or satisfactory. Nevertheless there is no doubt that they are hereafter to be very important and common.

Some varnish-makers make Kauri or Manila varnishes with unmixed tung-oil (prepared), adding the latter to the melted resin, running the heat quickly up to 600° F. or more to ensure combination, then cooling by throwing cold water (from a hose) on the outside of the kettle, to prevent jellying from too long-continued high heat. But it is more common to use mixed oil; and still more general practice to add the tung-oil as a rosin-tung-oil varnish.

A rosin varnish made with tung-oil and thinned to an unusual degree with mineral turpentine is a common vehicle in which to mix lithopone, making a paint which dries without gloss, and such are sold in great quantities as "flat wall finishes." They are spoken of elsewhere.

CHAPTER X.

JAPANS AND DRIERS.

These terms, japans and driers, are perhaps the most indefinite used in the varnish and paint business. It is commonly known that the Japanese and Chinese make varnishes of peculiar character, with which they make a beautiful glossy coating on articles of various kinds; and at one time, about the middle of the eighteenth century, imitations of this varnish, or varnishes made to imitate, rather remotely, the surfaces of this sort, were called Japan varnish. One way of doing this work was to put the varnished article into a hot oven and dry the coating from a melted condition, and the kind of varnish useful for this treatment came to be called japan, and the process japanning. This is one kind of japan made and used largely at the present day; but it is now almost always spoken of as baking-japan. The term japanning always refers to the use of this article. Another kind of varnish was also used to imitate this effect, and this was a thin liquid, which dried very rapidly and to a hard surface. It was possible to apply many coats of this, which was made to dry very quicky by being highly charged with lead compounds. From this kind of varnish the term japan has come to be applied to a liquid the most conspicuous property of which is its capacity of exceedingly rapid oxidation, brought about by loading it to saturation with lead and manganese compounds. These two kinds of japan are therefore as unlike as possible in appearance, composition, and use; and they agree only in perpetuating the record of failure of the European varnish-maker to successfully imitate the products of the country whose name they bear.

The subject of baking-japans will be reserved for a later chapter; the drying-japans and the driers form a class by themselves.

Driers.—It has already been explained that lead and manganese compounds of linseed-oil impart to the oil or varnish in which they are dissolved the property of more rapid oxidation; it may now be added that lead and manganese combine readily with common rosin, or colophony, to form resinates, and that these act in the same way when dissolved in oil or varnish, and that all such preparations are called driers. These compounds are made by heating the oxides of the metals with the oil or resin, and since this compound, which is liquid when hot, is a solid cake when cold, the melted mass is dissolved in turpentine or benzine, usually to a rather thin fluid. Various resins are sometimes put into the kettle with the oil and the oxides, shellac especially being used in this way, and either the lead and manganese combine to some extent with the resins and make an oil-soluble compound, or, more likely, the resins—which, not having been previously melted, are insoluble in oil—are soluble in the compound of oil with lead and manganese; at any rate, a compound is made which when diluted with turpentine or benzine possesses some of the qualities of varnish and not only dries quickly itself, but imparts that property to any paint or varnish to which it is added, and these varnish-like driers are called japans.

Japans.—Probably the original difference, if there ever was an original difference, between japans and driers lay in this, that a varnish resin was an ingredient of a japan, but the terms have now become so confused that any sharp separation by definition is impossible. Still there are substances to which the name of japan is given which no one calls driers, and there are driers which no one calls japans.

The action of driers may be best understood by first describing a different but analogous process, the formation of white lead or carbonate of lead from metallic lead and the carbonic acid of the air. Carbonic acid readily attacks metallic lead, but a very thin film is formed of lead carbonate which protects the metal beneath. The sheet of metallic lead is, therefore, put, loosely rolled, in a jar with a very small quantity of acetic acid. This acid eagerly attacks the lead, forming lead acetate. Carbonic acid is a stronger acid than acetic and it, in turn, attacks the lead acetate, forming lead carbonate, and the acetic acid is set free to attack a fresh quantity of lead, and this process goes on until all the lead is converted. At the close we should theoretically have all the acetic acid we began with; in practice some of it evaporates.

Theory of Driers.—Driers act in a similar manner, taking up oxygen from the air and giving it up to the oil. These driers are compounds of lead and manganese, in solution in the oil; these metals have the power of forming two sets of oxygenated compounds, the peroxidized ones having twice as much oxygen as the others. When in linseed-oil they give up half their oxygen to the oil; then, being exposed to the air, they absorb a fresh equivalent of oxygen, which again the oil takes from them; in this way they act as carriers of oxygen from the air to the oil, acting, of course, only when the oil is spread out in a film and exposed to the air. Since the oil is thus converted into a solid dry substance, these agents are called driers.

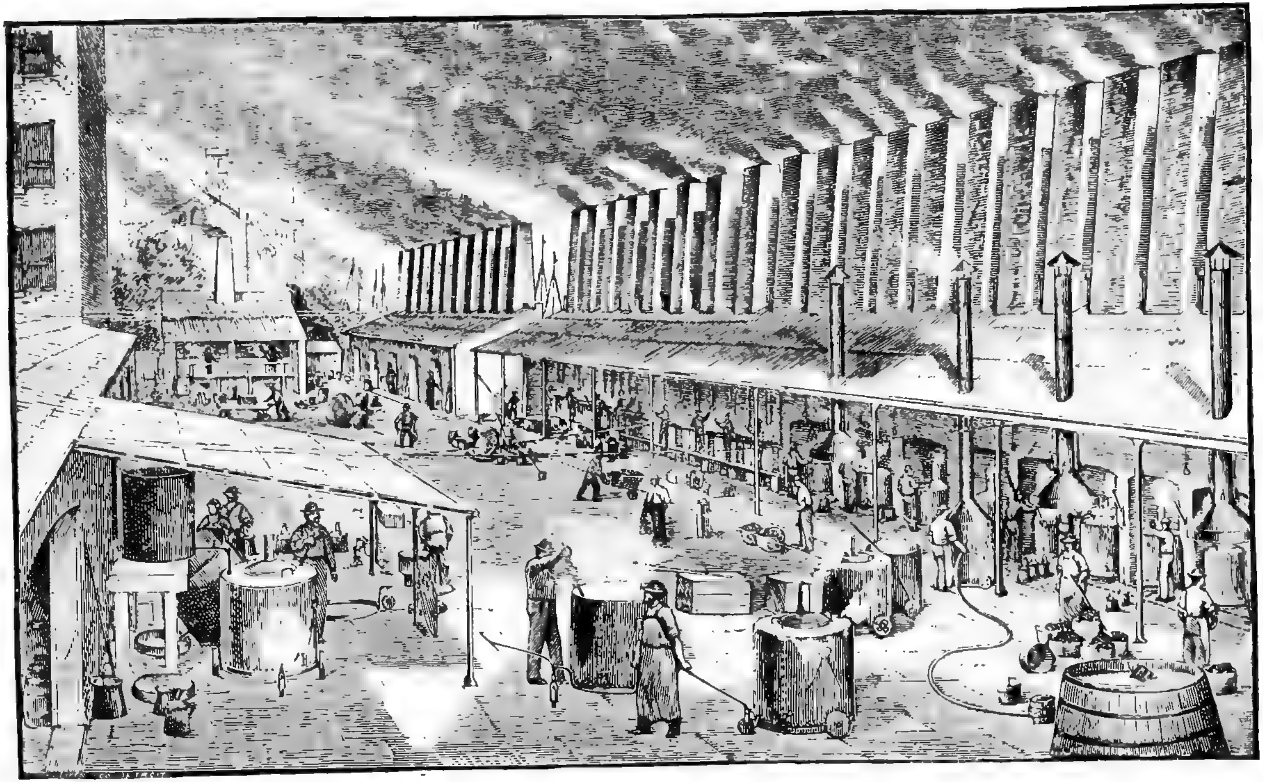
Driers; How Made.—The most simple drier is made by heating a gallon of oil with about four pounds of the lead and manganese oxides—in most cases there is a large amount of lead and a small amount of manganese—at a high temperature, from 500° to 600° F., until combination takes place; the resulting compound, which is black in color, is, while still warm, dissolved in turpentine. This high-temperature drier is highly oxidized. A much paler drier may be made by dissolving the lead and manganese in a larger amount of oil at a much lower temperature, and finally diluting with turpentine. This low-temperature drier is less highly oxidized, and driers of this class are believed to exert a less injurious action on paint than do the others, though all driers lessen the durability of the paint in some degree. Oil is often made to dry rapidly by adding some of these made-up driers to the oil, cold; such oil is called "bunghole boiled oil" and is not commonly thought well of; but some of the best authorities believe that such oil, if made with a low-temperature drier, is better than regular boiled oil; and it is a significant fact that many of the ready-mixed-paint manufacturers use raw oil and prepared driers, which they would not do if they thought it bad practice. Such driers as have just been described are pure and of the best quality. They may be cheapened by using rosin instead of oil, or by using rosin-oil to combine with the lead. These are diluted with benzine or a mixture of rosin or rosin-oil and benzine, and the odor of the latter disguised by some highly odoriferous essential oil, such as is obtained by the distillation of wood. Such products are less valuable, but most of the driers on the market are made in this way. The common compounds used for making driers are the oxides, but the acetate of lead and the borate of manganese are also used. These salts are white, and the supposition is that they make pale driers. When they are dissolved by heat in oil the acetic and boric acids are driven off, as the salts are easily decomposed and the acids are volatile, and there is probably no great advantage in their use.

Other compounds than those of lead and manganese are capable of acting as driers. It has already been said that cobalt and nickel will do this; iron, when in a suitable compound and dissolved in oil, is a powerful drier, not less active, apparently, than manganese. Copper, which is capable of existing in more than one state of oxidation, has not been considered as a drier, but recent experiments show that linseed-oil oxidizes much more rapidly in a copper kettle than in an enamelled one when heated and air is blown through it; and such oil contains traces of copper in solution; so that copper must be added to the list. There is a tradition that magnesia is a drier; but attempts made by the writer to make a drier of magnesia have not succeeded. It appears, however, that calcined magnesia is actually in technical use either as a drier or as a hardening agent in oil compounds, being added to the extent of 5 to 10 per cent. to the hot raw oil, with which it is strongly heated. Many things are done with linseed-oil which the paint- and varnish-maker know very little about. The people who use magnesia in this way call it a drier.

Since about 1910 considerable use has been made of cobalt as a drier. It is said that a very minute amount, about three one-thousandths of 1 per cent., of cobalt in a boiled oil is very efficient, and does not discolor the oil. It has been said, however, that such oil is liable to thicken, and probably to oxidize, by standing in the tank; hence it is to be used with caution. It is said by those who should know that it is an especially fit material to use as a drier in China-wood or tung-oil and its compounds; this oil responds to driers of every sort, and in fact has unusual drying powers of its own. Lead, manganese and cobalt driers may be made by combining these metals with this oil instead of linseed-oil, but the so-called "tungate" driers which have been received at the laboratory with which the writer is connected appear to be chiefly rosin compounds of very ordinary merit. In buying driers and japans the name of the maker should be considered as well as that of the product. This is also true of paints and varnishes.

Use of the Term "Drier."—The term drier is applied by those who are considering the theory to the metals, lead, manganese, etc.; by oil-boilers, etc., to the oxides, linoleates, etc., of these metals; and by the sales-people and the consumers to the oil-soluble compound, usually dissolved or thinned with turpentine or other volatile thinner. These preparations are of many kinds. What is sold in a paint store as a drier or japan is a liquid which when mixed with raw oil or paint in the proportion of 5 to 10 per cent. of drier will make the oil film dry hard enough to handle in twenty-four hours or less.

Acetate of lead is sometimes used instead of litharge, and borate of manganese is used as a source of manganese; the latter is often mixed with oil or varnish at a low temperature, say 90° to 130° F., and agitated for several hours; litharge is used in the same way; and borate of manganese is often added to oil, especially with air blowing, at temperatures not exceeding 340° F.; at this



VARNISH CHIMNEYS, YARD, AND THINNING-DOWN SHED.

By the courtesy of Berry Bros., Detroit.

latter temperature litharge is slowly taken up by linseed-oil in considerable quantity, and even manganese dioxide is absorbed in small but appreciable amount, especially if air is at the same time blown through it. This was the base of a well-known English patent many years ago; but the thing had been then practised many years in this country.

Driers Made from Soap.—Some years ago there was a great deal of drier made by making first a soda soap of the oil, and decomposing this cold, or nearly so, with an aqueous solution of the metallic salts, using the acetate or nitrate of lead and the chloride or sulphate of manganese. These cold-formed metallic soaps were then dissolved at a low heat in suitable solvents which would mix with oil.

A good example of such a drier is made as follows: To 20 pounds raw linseed-oil add 10 pounds caustic soda solution having the density 35° Bé., or enough to make a neutral soap. These are cooked together until the soap is made. This soap should then be diluted with 10 or 12 gallons of cold water and well agitated till the solution is complete. Then add slowly with constant stirring 25 pounds of solution of manganese chloride ($MnCl_2$) having a density of 35° Bé., or until in the clear supernatant solution no more precipitate is formed by another drop of the manganese solution. Remove the insoluble Mn soap thus formed, which is in irregular lumps; put it to drain on a rack covered with cheese-cloth and wash it well with cold water to remove the NaCl which has been formed. Drain as dry as practicable; this cake should weigh 25 pounds in its moist condition. This cake well dried is linoleate of manganese, and is an article of commerce; if dried at this stage it forms a dark-brown mass, soluble in oil. This moist cake, which is yellowish white in color, is put in 2 gallons of raw linseed-oil and slowly heated to evaporate the water, but the heat should not exceed 250° F.; when dry it may be thinned with 15 gallons of spirit of turpentine, and when well dissolved it may be further thinned with 15 gallons of "mineral turpentine." Another and better practice is to dissolve the moist cake, as before, in 2½ gallons of raw linseed-oil, then add enough more raw linseed-oil to make the total volume 12½ gallons and then add 25 gallons spirit of turpentine.

This makes a pale manganese drier, of which from 5 to 10 may be added to oil to increase its drying. If much more is added the oil film will remain soft, as this is not a "self-drying" drier. The best cobalt driers are said to be made in this way; but any such drier which is to be used in "boiled oil" is dissolved only in oil, no turpentine being used. A drier like the foregoing, which is a very thin liquid, is useful as a source of manganese for mixed driers. For example, we may heat a gallon of raw oil with a pound and a half of powdered litharge at 320° to 340° F., until the PbO is dissolved; this will take perhaps two or more hours, with constant stirring; if the PbO is allowed to settle on the bottom of the kettle (if over a fire) it will overheat locally and its desired character is lost; to this lead-in-oil solution we may add a gallon of the manganese liquid drier, and a gallon of turpentine, which makes a lead-and-manganese drier of pale color, and which is probably as good a drier for oil and paint as can be made from these metals. Similarly a fine japan drier can be made by dissolving lead oxide in a 10-gallon varnish (before thinning) and finally thinning it with this manganese drier.

Rosin Driers.—Lead driers may be made in the same way; also instead of oil common rosin may be saponified and rosin driers made; but this is not common, the more used practice being to melt the rosin, then gradually sprinkle in 5 to 7½ per cent. of powdered quick-lime (CaO), avoiding if possible the formation of lumps; the temperature must be raised just enough to keep the compound melted. Then gradually add the litharge (and red lead if any is used), and finally the powdered oxide of manganese. If any linseed-oil is used this is next added; but sometimes it is necessary to add part or all of the linseed-oil before the lead and manganese will go into solution. If lead acetate is used it is added the same as the litharge. If no linseed-oil is used it is sometimes difficult to dissolve the rosin-lime-lead-manganese compounds in benzine (or turpentine) because the melting-point is so high that the addition of even a little of the volatile thinner freezes it. Turpentine is a better solvent than benzine; but it is rather a shock to one's sense of propriety to put turpentine in rosin goods; sometimes a little kerosene, or better one of the newer high-boiling-point mineral volatile oils may be used to get the solution started. Great care should be used to avoid fire, which occurs in this high-temperature thinning oftener than from all other causes in the varnish factory, and is especially dangerous because the workman are right in it.

The chemical analysis of a drier is a difficult task, and when the results are obtained they are not of much use. To obtain special effects it is the practice of the makers to mix several driers of different qualities in certain proportions, so that really the best and most intelligent use of driers in an art rather than a science and calls for the knowledge of a specialist. For this reason, the analysis of a drier is of comparatively little value. To secure the proper drying of a naturally slow-drying paint with the least possible amount of drier, and to get the drier which will have the least deleterious effect on the paint, is a problem which calls not only for a great deal of knowledge of the matter, but also for a considerable amount of experimenting. A factory where such goods are made ought to have a laboratory where hundreds of carefully conducted and recorded experiments may be continually carried on. And when we come to the use of driers in varnish and varnish paints, the intricacy and difficulty of the problems become greatly increased, and even a small gain is often of great value.

Japans.—The term "japan" is also applied to substances which promote the drying of a paint-film. It cannot be said that there is any sharp line of definition between what are called driers and what are called japans, but what we usually apply the latter term to is a liquid which, by itself, dries to a hard film having considerable coherence. This is often produced by the use of some resin in the compound, not common rosin, or colophony, but some of the varnish-resins. Such a compound partakes of the nature of a varnish, and some of the japans, such as those in which colors are ground for coach-painting, are made from varnishes by heavily loading them with lead and manganese. Such japans would not be called driers; and on the other hand, some of the driers, notably the low-temperature driers, when evaporated leave a greasy metallic soap for a residue, and such a drier would not be called a japan, but the two classes shade into one another, and some preparations would be called driers by one man and japans by another. A japan always has a drying effect; that is, when added to oil it promotes oxidation in the film. The term "japan" is also applied to a totally different class of preparations, namely, such varnishes as are fused on the surface of metals and other substances by subjecting the coated article to the heat of an oven. These are also called baking-japans, or sometimes baking-enamels, and as they depend on the action of heat to harden them they are commonly made without any driers in them at all. There is not the least resemblance in composition or use between these japans and the other kind.

Bad Effect of Driers.—The danger from the use of driers in paint is this: Where oil without drier dries normally it absorbs a certain amount of oxygen and becomes a stable substance; no further oxidation takes place; but if it contains driers, they act as carriers of oxygen, and although their action is enormously decreased when the film hardens, it does not absolutely cease, and the effect is finally to oxidize the film to such a degree that its toughness is destroyed, so that the painter's saying that the drier burns up the paint is absolutely accurate. Since it is impracticable to get along without driers, as no one wishes for a paint which remains wet four to ten days, the paint expert uses all his knowledge and ability to make such a mixture of pigments and such a combination of driers as shall secure the greatest immunity from this result, in many cases with a good deal of success. But the subject is so intricate that it is impracticable to give rules regarding it.

Low-temperature Driers.—But it may be said that the low-temperature driers, which leave a greasy film when spread by themselves on glass and allowed to dry, are efficient driers in oil when added in small proportions, that is, up to the point where the oil itself is able to take up the lead and manganese contained, and if more of this same drier is added the excess acts as though no oil were present, and makes the film softer and more greasy, that is to say, slower in drying, in proportion to the extra amount of drier added. As such driers are made, 5 to 10 per cent. of the liquid drier is as much as should be added to a given measure of oil or oil-paint.

Self-drying Driers.—The high-temperature driers and japans, on the other hand, which may be called self-drying, and which when spread by themselves on glass dry rapidly to a hard film, may be added in any proportion to oil, and the more is added the more rapidly the oil will dry; and as a corollary, oil may be added to dilute and slow down paints ground in japan or a self-drying drier. This is not uncommonly done, in carriage-painting for instance, where the paint is ground to a paste in "grinding-japan."

Grinding-japan.—A grinding-japan is a sort of japan drier, but one which contains enough oil and resin to give it enough substance so that it may serve as a vehicle in which to grind pigments. This kind of japan must also have the property of mixing with the pigments used by the carriage-painter without chemical action, so that the paint thus made may keep without decomposition for a reasonable length of time, and must admit of being thinned either with oil, or turpentine, or both.

A typical grinding-japan is made about as follows: Four and a half gallons of oil is heated to 240° F. and 20 pounds of lead oxide (which in common practice is often ¾ red lead and ¼ litharge, but all litharge is quite as good) is gradually added and with it a pound of finely powdered manganese dioxide; this is stirred continually for two hours, at 390° to 400° F. When combination seems complete 10 pounds of good quality shellac (resin) is added, which will be in solution in ten minutes; then add 12 gallons of spirit of turpentine. The amount of oxides used is excessive; not all goes into solution; but it is commonly so made. A pale grinding-japan is made with 2 gallons of oil and 4 pounds of litharge and 4 pounds of shellac, at a heat not exceeding 340° F., and the Mn can be introduced in the form of the manganese liquid drier already described. This does not dry as well as the former, but well enough for most things, and is made for pale colors such as light chrome yellow.

From the fact that japans are mixed frequently with oil, it is not very uncommon for the purchaser to think that they should mix in any proportions without clouding, that is, without the precipitation of any of the ingredients of the japan. This is, however, not borne out by practice, for the japans which will do this usually contain little or no lead, which is the ingredient which should enormously preponderate in a really good drier, and japans which show a cloud when mixed in small proportion in oil are often those which give satisfaction in use.

Curdling.—This formation of a dark cloud in oil is spoken of by carriage-painters as "curdling" the oil, but no curdy precipitate is formed. The real value of a grinding-japan is known only by its practical use. It is easy to make a japan that will not curdle, but none such has come under the observation of the writer which is of much value as a grinding-japan. Another thing which often unnecessarily alarms the purchaser is the deposition of a sediment, or "foots," from a clear or "bright" japan or drier. This, it may be said, is almost or quite invariably the case with driers containing lead if allowed to stand a considerable time, also of low-temperature manganese driers, and is not to be taken as a bad sign unless it goes on to such a degree that the drying effect of the drier is evidently impaired, which may sometimes be the case with manganese driers. It is probably good practice to avoid carrying a very large stock of driers and japans, which do not improve by age beyond two or three months, and in general it may be said of varnishes that they improve with age for a considerable time, and then do not deteriorate, while paints of all sorts, and especially those ground in varnish and japan, are never so good as when they come fresh from the mill. It is obvious that as the chemical composition and stability of pigments, and especially of those colors called "lakes," vary, it is desirable to use with them such japans and varnishes as will make the most permanent and stable mixtures; this is only to be known by experiment, though, of course, the experience of the manufacturer is a valuable guide in making new mixtures, and so it comes that the business of making these japan colors and varnish paints is largely in the hands of the varnish-makers, who know most of the actual composition and nature of the materials used.

The activity of the business of making mineral and lake pigments, which is incessant, leads to the continual improvement (that is, change) of composition, and introduction of new colors, and there is likewise change in varnish materials, especially resins, and processes; so that a considerable proportion of the formulæ in use five years ago are now out of date. Even where names are preserved substances change and formulæ become misleading. It is but another case where "the letter killeth; the spirit giveth life."

CHAPTER XI.

ROSIN.

Common rosin, or colophony, is the residue remaining in a still after the spirit of turpentine has been distilled off from the crude turpentine which is obtained from the pine-tree. It is commonly supposed that this crude turpentine consists of colophony dissolved in spirit of turpentine. If this were so, it should be possible by redissolving the rosin in the essential oil to reproduce he crude turpentine, but this is not possible; that is, it is easy to dissolve the rosin in the spirit of turpentine, but the substance so obtained does not much resemble crude turpentine.

Spirit of Turpentine an Artificial Product. — The characteristic and peculiar odor of spirit of turpentine is almost or quite absent from crude turpentine, and the probability is that the latter is decomposed by the heat in the still, and that the spirit of turpentine and colophony are both products of this decomposition, which is a chemical rather than a physical one, being in this similar to the change which we know takes place when ordinary varnish-resins are melted and decomposed in the varnish-kettle by heat. In the latter case the temperature of the melting and decomposing resin is far higher than that of the vapor given off, thus conclusively proving that the change is chemical and that the liquid which distils off is a product of destructive distillation, a fact which we know from other reasons also; and although the writer has not had an opportunity of running a turpentine-still, he has supposed that a destructive distillation occurs in it and that rosin, or colophony, and spirit of turpentine are not natural substances, but products of chemical action.

Recently a high authority has expressed the opinion that rosin is a decomposition product, but that the essential oil is present in the pitch as it comes from the tree. It is true that this has not the well-known odor of spirit of turpentine, but this odor is probably not necessarily present; in fact, when fresh balsam from a new tree is distilled the spirit which comes off has only a faint aromatic odor, and the smell commonly associated with "turps" is probably an oxidation-product of some impurity.

Chemically considered, rosin is an acid substance; it in fact consists mainly of a mixture of organic acids and therefore it has a strong disposition to unite and combine chemically with basic substances, such as soda, potash, lime, etc. It combines with soda and potash to form rosin soap, a yellow soap somewhat similar to ordinary tallow soap. This will mix in all proportions with common soap, and as it is not entirely without detergent properties and is very cheap, it is largely used as an ingredient, and is commonly spoken of as an adulterant, of laundry soaps. It is well known that the soda and potash compounds are soluble in water, but the lime soaps are not, neither are those of the metals, such as manganese and lead. These lime and metallic resinates are soluble in oil or turpentine and are used in varnish and driers. The resinates of lead and manganese being efficient and cheap driers are very extensively used. They are not as valuable as oil driers, their influence being more deleterious to the durability of whatever they are put in than is the case with oil driers, and are somewhat unstable compounds, which makes them rather unreliable. Rosin will dissolve readily in oil, and a varnish may be made in this way, but such a varnish remains for a long time tacky and never gets very hard, particularly if much rosin is used.

Rosin Hardened by Lime. — It has been found that the addition of from 2 to 10 per cent. of lime to rosin hardens it considerably, 5 or 6 per cent. of lime being the quantity most commonly used; it is added to the melted rosin and quickly combines with it, but a part settles out, it having been found more convenient and expeditious to add more than will readily combine under the common conditions of heat and time allowed. This hardened rosin may be easily dissolved in oil, and really forms the base of about all the very cheap varnish on the market. A patent, which has now expired, for this lime-hardening of rosin was granted, but the process was before that well known to all varnish-makers and, so far as is known to the author, no regard was ever paid to the patent, in this country at least. I am told that it is described in an English book of the eighteenth century. As a general rule, when rosin is spoken of by American varnish-makers they refer to this lime-hardened article, which they prepare as they want it. The common practice is to use pulverized quicklime; formerly slacked lime, or calcic hydrate, or a mixture of that and carbonate was used. Varnish may also be made by dissolving rosin, either in its natural state or hardened, in turpentine or benzine, making a product somewhat like damar varnish, and this is used to adulterate damar varnish or as a substitute for it; it is also used to adulterate other varnishes. One of the most important uses of rosin varnish is as an adulterant of regular oleo-resinous varnishes, but a large amount is sold for use without any admixture of the more valuable ingredients. These rosin varnishes are pale in color as a rule, and of a brilliant lustre when recently applied. They are free or nearly so from most of the "tricks" (formation of an uneven and imperfect surface) to which better varnishes are liable, but they do not usually dry to a very hard surface (but much progress has been made in late years in this regard), and they lack durability, especially when exposed to the weather.

Good Effect in Mixtures.—The addition of a very small proportion of rosin varnish to an oleo-resinous varnish often makes it ready for use in a short time. This may be due to two causes, one of which is that the rosin is acid and combines with any of the excessively minute particles of lead or manganese which may be floating in the varnish and which would cause flaws and imperfections in its surface; the other that rosin is slow to set and harden and may act in the film as a flux, causing the film to flow more evenly and thus making a more perfect surface.

It may not be necessary to add, in order to secure these results, more than 3 to 5 per cent. of rosin varnish containing a still smaller per cent. of actual rosin, and this small amount may not be enough to be sensibly deleterious, especially in a varnish of moderate price and ordinary character. As a general rule, the addition of rosin varnish is made in considerable quantity, as it must be to sensibly affect the price, and is an injurious ingredient.

Viscosity of Rosin.—Rosin is a brittle solid, easily reduced to a powder, but if we lay a piece of rosin on a board, even in a moderately cool room, it will in time flow out into a flat cake. If we remove the head from a barrel of rosin and lay the barrel on its side, the rosin will in time flow out. It is in fact intermediate in its properties between a solid and a liquid, being extremely viscous. It is very easily melted, and as a liquid has unusual solvent qualities; it is a very effective flux.

This was known to the old varnish-makers, who, as has been seen in the recipes already given, often put a small proportion of it in the kettle in which they were about to melt their resin; by doing so, the regular varnish resin was much more easily melted. Sometimes a little oil was added for the same purpose. It was common to rub the inside of the kettle with oil before putting it on the fire, but rosin is much more effective.

Used with Asphaltum.—Rosin easily dissolves and is dissolved by the asphaltums when melted, and is a common ingredient of asphaltum varnishes and compounds. It adds so greatly to the working qualities of these asphaltum compounds that it is difficult to resist the temptation to put it in, and since most of the asphaltum compounds and varnishes are sold at a low price, and as rosin is the very cheapest thing used in the business, the temptation is twofold.

Rosin Varnish Cracks.—Every one must have observed on old doors and sometimes on old furniture, especially chairs, that the paint is cracked and the cracks have opened to a considerable width, frequently a quarter of an inch, in a reticulated pattern suggestive of alligator-leather. These cracks are at first minute; then the paint or varnish on the interspaces contracts, drawing slowly apart, until the cracks become wide bare strips. In nearly all cases this is due to the use of rosin varnish, either by itself or as a considerable ingredient in a paint. India-rubber as a constituent of paint or varnish will act in the same way; but practically it is not in use. If a rosin varnish is made with very little oil, it presents at first a brilliant and glassy surface, because of the high percentage of resinous material, but the air rapidly acts on it, possibly because the minute proportion of ammonia in the air (which is much higher indoors than without) chemically attacks the rosin, but also because pure air acts on it as well, and in a short time the lustre is greatly reduced; then it begins to show under a magnifying-glass minute cracks; these grow larger; after a time the whole of the varnish cracks in pieces and comes off. If a considerable amount of oil is used, the lustre is not at first as good, and although it nearly disappears in a comparatively short time, the varnish lasts much longer than the one just described, and it is this sort of varnish (or the first kind mixed with an oil-paint, which has the same effect in increasing the proportion of oil) which shows the wide reticulated cracks spoken of; the rosin varnish which is nearly all rosin usually falls off entirely before the cracks become so wide.

Rosin may be hardened by zinc oxide, or by white lead, instead of lime, and a rosin "ester" has been made in which the rosin acids are combined with glycerine; these products are better than the lime-hardened article, but they also cost more and are darker in color, and it soon becomes apparent that a varnish can be made for about the same money out of a cheap Manila or other cheap resin, which will be for actual use worth ten or twenty times as much as the rosin varnish; so that practically the limed rosin is the compound in actual use. Most of the recent writers on the subject have laid stress on the fact that lead and manganese tend to shorten the life of paint and varnish; the writer of this has been as strenuous in insisting on this as anybody; but the fact is that, excepting a small amount of varnish for special and very limited use, all varnishes except rosin contain some lead; the manganese is commonly so small in amount as to escape detection by chemical analysis, though not unimportant in its action; but the presence of lead in a varnish, being with our present practice unavoidable, is not to be taken as an objection, but rather the contrary, while varnish containing lime may be confidently rejected, as being a rosin varnish. The author does not, however, regard the absence of lime as a definite proof of absence of rosin, for evidence is at hand that rosin varnishes are made without lime, although the writer does not know as yet how they are made; the making of rosin varnishes is quite an industry by itself, and those who are engaged in it undoubtedly have been working out processes and using materials not known to those who are less familiar with that branch of the business. It is not to be supposed that rosin varnishes as a rule do not contain some lead and manganese; as a rule they do. Rosin is so soft that varnishes containing it naturally dry slowly, and the makers put in anything which will hasten their drying; but it is possible, and not very uncommon, to make rosin varnish without these driers.

I cannot refrain from giving an illustration. Some years ago I had occasion to give advice about varnishing the woodwork—posts, beams, doors, etc.—of a chemical laboratory in one of our universities. As I have spent the greater part of my life in a laboratory and not a little of it in the varnish business, it did not occur to me that I did not know practically how to varnish a laboratory, and I advised using a varnish with about 20 gallons of oil, and made, as nearly as I now recollect, of Kauri, Benguela, and Zanzibar resins. The head professor of chemistry had, however, formed the idea that lead, even in traces, was objectionable, not, however, because of its oxidizing action, but because he feared it would be attacked by sulphuretted hydrogen, which is always present in the air in such a laboratory. Of course all chemists know that it does attack lead, and white-lead paint in a laboratory quickly becomes blackened from the conversion of the carbonate into sulphide; but in varnish there is very little lead, and what there is is probably so firmly combined that hydrogen sulphide cannot attack it; and besides all that the fact is that any decent varnish is nearly impermeable to gases after it has become well hardened; it wastes away from the outer surface, or it cracks from too rapid changes of temperature, or it is thrown off by moisture in the underlying wood, trying in vain to pass through it, but it is not penetrated and decomposed throughout by gases, so that the reasoning which applies to an oil and pigment paint does not bear on the varnish problem; but this was all unknown to the professor of chemistry, a man of much learning and eminent in his own way, and he insisted on having a varnish free from lead. I gave it up, wondering in my own mind what new and unknown star was arising in the varnish world who had solved the problem of making a raw-oil varnish without driers for such use.

The next time I saw the laboratory I found out. That beautiful building had been subjected to the outrage of varnishing it with the meanest kind of a rosin varnish, a cheap and much worse than worthless "hard oil finish," three-fourths of which had decomposed and fallen off, leaving dingy patches of rosin on the blackened surface of the wood. But it had no lead in it, nothing but lime. In the same building the desks, stair-railings, etc., which had been bought ready-made from some respectable manufacturers, and varnished with a good though not expensive varnish, were in as good condition as when bought, ordinary wear excepted.

Rosin Size.—A solution of rosin, without any treatment, in benzine is probably the cheapest varnish in use. I have seen it sold in barrels for nine cents per gallon, f.o.b. cars. It is used for varnishing building-paper and the like, but building-paper is sometimes sized with a rosin size, which is added to the pulp, and a great deal of this size is used for varnishing wall-paper.

The rosin varnishes are much less impermeable to water than those made from standard varnish-resins, and when a rosin varnished surface is wet with water it usually turns white because of the action of the water on the rosin. Many varnishes not containing rosin do this also, but not so readily, nor does the water penetrate them so deeply.

Sponge Test.—If we place on a flat horizontal varnished surface a wet sponge, and leave it overnight, we shall find in the morning whether the water has acted on it or not. A rosin varnish will be white under the sponge, and frequently it will be dissolved out down to the wood or nearly so, and this white surface will remain white when dry, showing deep corrosion. A better varnish, although it may turn white, will regain its original color on drying, and a varnish made expressly to stand water ought not to be affected.

Rubbing Test.—If the reader will rub the varnished surface of a piano or of any good piece of varnished furniture with the ball of the finger, he will find that no effect is produced, except to increase the polish; but if the same thing is done to a surface covered with rosin varnish, the latter can be rubbed off in this way, showing that it is softer and less tough than the better article.

Rosin varnishes are chiefly used on the woodwork of the cheaper class of houses, on cheap furniture, and on agricultural machinery. They are also used to mix with the better varnishes in order to reduce the price, and there is a great retail-store trade in these goods. Every retail dealer in paint and varnish keeps two or three barrels of rosin varnish on tap, from which he sells varnish to the house-painters and other people under any name by which they may demand it. It is probable that more rosin varnish is sold than of all the rest put together. It cannot be denied that progress is being made in producing better qualities of these goods, but it does not now seem likely that they will ever equal the varnishes made from the natural resins, either in appearance or durability.

CHAPTER XII.

SPIRIT VARNISHES.

If we put some shellac resin, or gum shellac as it is called, in a bottle with somewhat more alcohol than enough to cover it, and let it stand a day or two, occasionally shaking it, the greater part of the resin will dissolve, making shellac varnish. The solution will take place much more promptly if the bottle is placed in a shaking-machine, or attached to a revolving shaft, and the common way of making shellac varnish is to put the components in a revolving barrel or churn, or in a mixer where the materials are agitated by a stirrer. In any case, it is done without the application of heat, and the varnish thus made is a spirit varnish containing no oil, nothing but a resin and a volatile solvent. The part which does not dissolve is a sort of wax, in appearance (when purified) not unlike carnauba wax; this is soluble in benzine, and may be removed from the shellac proper by the use of that solvent, leaving a clear and transparent solution of the pure resin in alcohol.

When shellac varnish is spread on a surface the alcohol evaporates and the resin, or the mixture of resin and wax, is left as a film of exactly the same composition as the original resin; the office of the alcohol having been to facilitate the mechanical operation of spreading the resin out in a thin film of nearly uniform thickness. This is very different from the action of oil in oleo-resinous varnishes, which not only helps to reduce the resin to a liquid condition, but itself remains as an important and valuable part of the film. Shellac varnish is, therefore, essentially different from those varnishes which have so far been described. It is the most generally used and the most important of the spirit varnishes.

Composition of Shellac Varnish.—The English and European books on this subject commonly contain formulæ for making it with from five to fifteen or twenty parts by weight of alcohol to one part of shellac. This will make a very thin varnish and is not known commercially in this country, where ordinary or standard shellac varnish is made with five pounds of gum shellac to one gallon of 95 or 97 per cent. alcohol, or about one part by weight of shellac to one and one-half parts by weight of alcohol. This makes a varnish of rather heavy body, but one which may be brushed out thin, and will dry quickly. All varnishes should be put on in thin coats, but shellac is remarkable in this respect, for if put on thin it dries very quickly and if put on thick it takes on a waxy consistency and is excessively slow about getting hard.

Precautions in Using Shellac.—One or two thin coats of shellac may be applied and the object put to almost immediate use, but great care should be observed in using more than two coats or this persistently tacky condition may be encountered. As shellac is a varnish very commonly used by amateurs, this is worth remembering. Shellac very easily softens and melts with heat, and if it is used as a first coat on woodwork and an oleoresinous varnish put over it, the object so coated should not be placed near a fire or in the hot sun, lest the shellac soften and blisters be formed.

The natural color of shellac is brownish yellow or reddish yellow, and it is commonly spoken of as orange. The different grades are designated by letters, D. C. being the best (the letters are the initials of David Campbell). It is reported, and is probably true, that large quantities of common rosin are shipped to India and used as an adulterant of gum shellac in making the cheap grades.

Shellac is easily bleached with chlorine, becoming nearly white, and called then white shellac.

Orange shellac is soluble in 85 per cent. alcohol, but white shellac which is bleached in an alkaline aqueous solution, from which it is recovered by acidifying the solution, contains some water and, perhaps for this reason, requires strong alcohol, 95 to 97 per cent., to dissolve it. Some of this water may be removed by coarsely powdering the shellac and exposing it on trays to dry air in a warm but not too hot room.

Insoluble White Shellac.—If too much heat be applied, or if the drying operation be too prolonged, the white shellac is very liable to go over into an isomeric state and is then perfectly insoluble. It is, therefore, stored in a cool damp place and when wanted is got into solution with the utmost expedition. Orange shellac requires no such care and may be used even after it has been melted.

Shellac is not only soluble in common grain-alcohol (ethyl alcohol), but also in wood-alcohol (methyl alcohol), and in some of the other alcohols, but ethyl and methyl alcohols are the ones commonly used. It is readily soluble in ammonia-water, also in aqueous solutions of borax and of the carbonates of soda and potash.

Alkaline Solutions.—The ammonia solution has had some use, especially as a polish for shoes, etc., and the borax solution has some commercial use, especially, I have heard, as a glaze for straw hats. Any of these varnishes may be colored by the addition of a suitable dye or may be made into a varnish paint with a pigment which has no chemical action on the shellac. There are places where shellac is the best varnish that can be used; for instance, nothing equals it for varnishing the wooden patterns from which castings are to be made, and for floors on ships where it is absolutely necessary that they should be ready for use within an hour or two after they are varnished; it is, in fact, used not a little for a floor varnish in houses, but it lacks durability, and in general it is easily destroyed if exposed to the weather. It dries more quickly than any other common varnish and on that account is very useful.

Damar Varnish.—As shellac may be taken as a type of the alcoholic varnishes, so damar may represent that class which has an essential oil as the solvent. Damar varnish is made by dis solving damar resin in spirit of turpentine. This may be done cold, in a revolving barrel or churn, or hot in a kettle. If the latter, it is common to dissolve it in a small amount of turpentine, and when it is dissolved thin with the necessary amount of cold turpentine. This lessens the fire risk. It is not a perfect solution, remaining persistently cloudy, an opaque white liquid, becoming more translucent by standing a long time. It dries by the evaporation of the solvent, but, as has been said before, turpentine does not wholly evaporate, part of it becoming oxidized and remaining as an elastic resinous ingredient of the film. Damar itself is not a hard resin, but it is very white and the varnish film never becomes very hard (unless by baking), nor is it very durable, even within doors, but its extreme paleness and the ease with which it may be used cause it to be very popular. To cheapen it, benzine is often mixed with the turpentine and rosin with the damar resin; in fact, not a little is sold under the name of damar, which contains no damar and no turpentine. Mixtures of this sort may be made which will deceive all but the very elect. Perhaps some of these are about as good as the straight damar, which is not a very good varnish anyway; still, the people who use it for fine work, such as fine baking enamels in delicate colors, can tell the difference and not only insist on pure damar, but like that made from selected pieces of resin. There is a general belief that if it is made by the cold process it is better than if made hot. It is usually made by dissolving five or six pounds of damar resin in one gallon (seven and one-fifth pounds) of spirit of turpentine. It should be allowed to settle for sixty days before using.

Sandarac.—Another resin of some importance is sandarac. As has been already frequently stated, this was one of the first known of the resins, and varnishes were made of it perhaps in prehistoric times; certainly in early times. It is soluble in alcohol (not perfectly), also not very perfectly in spirit of turpentine, with heat in oil, and has been a considerable and frequently the most important ingredient in varnishes of a complex character. It may be observed—and the observation really lies at the foundation of the art of making spirit varnishes—that when a resin is found to be only partially soluble in a liquid, complete solution may be attained by adding some other resin to the mixture; sometimes by adding the dry resin, at others by dissolving the second resin in the same or some other solvent and mixing the solutions. Common rosin, or colophony, is remarkably efficient in this respect, and it is said that Venice turpentine, Burgundy pitch, and the like are also valuable. Sometimes a resinous solution will dry flat, i.e., white and opaque, and the addition of a portion of some other varnish will cure this tendency, making the film full and transparent. Thus the art of making spirit varnishes is one of great complexity, and the writer of this is no more than an amateur in this kind of work. His advice and information to the reader will, therefore, be correspondingly scanty.

Sandarac, when new and fresh, is of a pale-yellow color, and with age becomes reddish and darker; when applied as a varnish it is left on the surface as a resin and, as would naturally be supposed, darkens and becomes red. This has long been known, for it has been used from early times to varnish pictures, and its effect on their colors was a subject of comment among the painters of the middle ages. They usually dissolved it in turpentine and commonly added some other resin to the solution.

What has been said about sandarac may be applied to mastic: it is only partially soluble in the ordinary solvents; alcohol dissolves about nine-tenths of it; turpentine is also a common solvent for it. It is paler than sandarac and does not redden or darken with age. It is somewhat softer than sandarac.

Damar, shellac, sandarac, mastic, and common rosin are (except asphaltum, to be spoken of later) the only resins commonly sold by dealers in varnish resins in this country for making varnishes of this class, i.e., solutions of resin in volatile solvents, without oil. There are many other resins soluble, or partly so, in alcohol or turpentine, which are said to be and probably are used in spirit varnishes, prominent among which are elemi, Venice turpentine, Burgundy pitch, and benzoin; these are to be had from importers and dealers in drugs and are by them said to be used in the manufacture of medicinal preparations, plasters, and the like, and toilet articles. Probably a small amount also goes to the spirit-varnish makers, but the market shows that the resins first mentioned are the ones from which nearly all the spirit varnishes are made. There are also a number of tinctorial resins, such as turmeric, gamboge, dragon's blood, annatto, and the like, but the spirit-soluble coal-tar colors have largely displaced them, so that they are hardly worth mention. The opinion of the writer, founded on considerable evidence and some knowledge of the subject, but yet not that of an expert, is that shellac cleared of wax is the foundation for most of the spirit varnish, its defects corrected by mastic and sandarac (which latter are also used considerably without shellac), and cheapened when necessary with rosin. The solvent is chiefly wood- or grain-alcohol, more frequently the former, not only because it is cheaper but because it is better for making the wax-free shellac solution.

Alcohol will dissolve about 20 per cent. of benzine, and this may sometimes be used to cheapen the mixture, and probably in some cases to increase its solvent power, and a little oleo-resinous varnish or a little oil may be added in some instances to give certain qualities. There are, of course, other solvents, the most important being coal-tar naphtha, great quantities of which are used in making varnish for ships'-bottom paints; amyl acetate and fusel-oil, which are used in the pyroxylin varnishes, and carbon disulphide, used in certain asphaltum paints; and solvents obtained in the fractional distillation of wood-tar are used in varnishes which are made and used in certain manufacturing operations, but the spirit varnishes of the market are probably of the composition indicated. A considerable quantity is imported, chiefly from France, and it is commonly believed in this country that the French make more spirit varnishes, and know more of them, than do the people of any other country, although they are believed to be deficient in knowledge of the better sorts of the oleo-resinous varnishes.

Closely allied to the spirit varnishes are some of those made with asphaltum. This is a black or brownish-black resinous mineral, soluble in spirit of turpentine, and when melted mixing in all proportions with linseed-oil, also with melted rosin, and the solutions of it mix readily with the oleo-resinous varnishes. Like rosin, it has considerable effect as a flux; but unlike rosin, the hard varieties are highly permanent and durable, and where the color is not an objection, it is a valuable ingredient in oleo-resinous varnishes. It has a rather bad name, due to several causes. In the first place, its warm brownish-black translucent color (in a thin film) has always been an attraction to artists, and the artist is too often totally and phenomenally ignorant of the materials, and especially of the vehicles and varnishes, which he uses, but not lacking in confidence. Hence asphaltum dissolved in turpentine has been used, and this, especially if mixed with rosin, is merely a spirit varnish, and is one of the most perishable of varnishes, because the vehicle evaporates and leaves the asphalt in a thin film, which either immediately or very soon becomes a powder; or, if mixed with rosin, cracks; and in any case is almost certain to partly dissolve or be dissolved in the other paints used on the same work, dissolving and destroying them. For these and other reasons the belief has grown up among artist painters that asphaltum is unstable and in every way dangerous. This is all wrong.

Stability of Asphaltum.—The great painters of the middle ages used asphaltum freely, and in their hands it proved absolutely permanent, and Eastlake says that there are no complaints by any of the writers of that period of its flowing or cracking. The reason is that they used it in a true oleo-resinous varnish, which dries too slowly for modern practice, but which is the only way to attain permanence. Another reason for its evil repute is that it has been and is largely used as a cheap black varnish for small (and large) pieces of iron used in the arts and manufactures, as an inexpensive temporary finish, keeping them from rusting until they come into the hands of the consumer. The way to make a cheap asphaltum varnish is to melt it with rosin and thin with benzine. The most durable asphaltum is not very black, but brown and translucent as a film, so a softer and blacker material is used, much more opaque but less durable. This is not all. Much cheaper than asphaltum is coal-tar pitch, and a great deal of asphaltum varnish is made of this, which is inferior to asphaltum in every respect, even, unfortunately, in price. Such varnishes are sold for fifteen cents a gallon, perhaps less. On the other hand, if we substitute the best and hardest asphaltum for all or a portion of the varnish resins in an oleo-resinous varnish, particularly one containing considerable oil, we find that such a varnish is very slow to dry, and if we accelerate the drying by lead and manganese driers, we are liable to add so much drier that the varnish is shortly destroyed by their excess. But if we make such a varnish and resolutely give it time enough to dry, we find it to be a material of the highest excellence. Asphaltum seems to be between soft bituminous coal on the one hand and liquid petroleum on the other. The hardest varieties are the Egyptian and that known as gilsonite, which comes from Utah. These are so hard that they are very brittle, easily powdered, and at ordinary temperatures the pieces have no more tendency to stick together than pieces of coal. Trinidad asphaltum, on the other hand, contains so much mineral oily matter that pieces which are pressed together readily though slowly unite, and if a barrel of it is laid on its side with the head removed the asphalt will in time flow out of the barrel. It has about the consistency of soft rosin. Many intermediate grades are found and also some which are even softer than Trinidad, shading off indeed into heavy petroleum. From some of these heavy mineral oils, notably those from California, a residue from distillation is obtained very much like the natural soft asphalts.

Maltha.—This residue is known as maltha, a Greek name for soft asphaltums, and is of varying consistency, according to the temperature at which the distillation has stopped, and which is varied according to the use to be made of the residue.

P. & B. Paint.—In 1886 a patent was issued to Pearce & Beardsley, two citizens of California, for a paint or varnish made by dissolving this maltha in bisulphide of carbon, a preparation which attained a considerable degree of popularity under the name of P. & B. paint. Bisulphide of carbon is a volatile liquid which has the singular property of thinning maltha very rapidly, so that a small quantity of it produces as great an effect in making the compound fluid as several times as much spirit of turpentine would have. Hence a varnish can be made in this way which is almost all solid matter, and a much thicker layer can be applied than of any other material. This is in itself an advantage, but it is accompanied with the disadvantages that the compound easily thickens by the spontaneous evaporation of even a small amount of the thinning material, and also that the vapor is highly poisonous and explosive. It has, in spite of these drawbacks, proved useful for many purposes. All these soft asphalts owe their flexibility to the mineral oily matter which they contain, and retain it if kept in masses of considerable thickness, for example, in street pavements and the like; but when made into varnish and spread out in a thin film, the ingredient which gives them flexibility is absorbed by and passes off in the air and rain, and the earthy constituent alone is left, without coherence, which becomes a powder and falls off. If we start with a hard asphaltum like gilsonite, we find it necessary to add to it something to make it coherent and elastic.

Permanently Elastic Asphaltum Varnish.—This may be done by dissolving it in linseed-oil, and this, unlike the mineral oil of the soft asphalt, is permanent, and a film of such a varnish retains its elasticity as well as one made from oil and the best varnish resins. Varnishes may be made in this way of hard asphaltum and hard varnish resins with linseed-oil, which have fine lustre and extraordinary durability. They are usually rather slow to dry, but this is less marked than when asphaltum alone is used with the oil. What is commonly sold as asphaltum varnish is a solution of asphaltum in turpentine or benzine, mixed with a varying amount of quick-drying varnish, usually rosin varnish, but asphaltum varnishes differ greatly in quality and price. Some important uses of asphaltum will be described in later chapters.

CHAPTER XIII.

PYROXYLIN VARNISHES.

It has long been known that when cotton fibre (or in fact any form of cellulose, as woody fibre in general is called) is immersed in nitric, or, better, in a mixture of nitric and sulphuric acids, for a very short time, and then removed and well washed, it is found to have undergone a chemical change, although its outward appearance is the same as before. One of the most conspicuous things about this change is that while before it was very combustible, afterward it became highly explosive; the explosive thus made is called guncotton. Before nitrating, the cotton or other fibre is insoluble in almost every known liquid; afterward it is easily soluble in various alcoholic and ethereal solvents. Cotton thus treated is also called pyroxylin, nitrocellulose, and soluble cotton, as well as guncotton, and may be made of a considerable variety of composition, according as it has been more or less acted on by the acid. A suitable compound of this sort, dissolved in a mixture of ethyl alcohol and ether, is the collodion, or "liquid court-plaster," of the pharmacists, which, on being applied to wounds, dries almost instantly and forms a film like an artificial skin, which protects from dirt and infection. This is probably the earliest use of a pyroxylin varnish, and is still an important one.

The commercial use of pyroxylin lacquers for adorning and protecting manufactured articles is a subject of interest and importance. The writer has had no experience with these varnishes, but is fortunately able to supply the deficiency by the aid of his friend, Mr. E. D. Williams, Superintendent of the Celluloid Zapon Company of Stamford, Conn., the largest and most important manufacturers of these products in this or any other country; hence the reader may accept with confidence the following outline of the subject:

Collodion.—The earliest use in the arts of a pyroxylin varnish was in the application of collodion to photographic plates; when the wet method of preparing and using such plates was in vogue collodion was an important part of the photographer's outfit; and although dry plates are made without its use, it is more used in photography than ever, as it is now used for making the flexible films used in "Kodak" and other film cameras.

Kodak Films.—For this purpose a methyl-alcohol solution is used. The Eastman Kodak Company is said to make a solution as follows: 97 per cent. methyl alcohol, 65 parts; amyl alcohol, 25 parts; amyl acetate, 10 parts. To a gallon of this solvent 16 ounces of pyroxylin is added. This varnish is spread on long glass plates previously coated with a thin solution of paraffin to prevent adhesion. This work must be performed in a room the air of which is as dry as possible, to prevent the hygroscopic wood-alcohol from taking up water. The air is dried by passing it through refrigerating coils, by which means the moisture is precipitated; when the air subsequently rises in temperature it is dry in the sense that it will no longer give up moisture. The films are finally stripped from the glass plates and coated with the sensitive emulsion, thus producing a flexible sensitive plate which will withstand the various chemicals used in photographic developers. A thin solution of pyroxylin in wood-alcohol or other solvents is also often used to flow over the developed negative to protect the gelatine film from being scratched or absorbing moisture. Many photographers use this same solution to varnish their finished pictures. When thus protected, negatives and pictures can be handled with little fear of injury,

As soon as pyroxylin varnishes came into extensive use for photographic purposes, other uses suggested themselves; but in order to adapt them for use on metals and wood, solvents had to be found which would not dry too quickly or take up moisture from the air and thus cause precipitation of the pyroxylin. Among the solvents which were early discovered were nitrobenzole ("oil of mirbane") and acetic ether, both of which were used in conjunction with methyl alcohol, and as the alcohol evaporated first, the resulting film, even though it turned white, would eventually clear up, as the slower-drying solvents remained until after the water had evaporated and redissolved any pyroxylin which might have become precipitated.

As these mixed solvents had many objectionable qualities, and the demand for a lacquer suitable for polished metallic surfaces increased, a great deal of research work was done to find suitable solvents for nitrocellulose which would dissolve it perfectly and make a lacquer which would dry slowly enough in the air to give a uniformly smooth, clear, transparent film which would not impair the lustre of these polished surfaces and would adhere to them. Camphor and all crystalline substances had to be eliminated, as they would recrystallize on drying and give a dull finish.

Solvents.—Among the solvents which we find mentioned in the early history of the subject are acetone, nitrate of methyl, butyric ether, valeric ether, benzoic ether, formic ether, salicylate of methyl, formate of amyl, acetate of amyl, butyrate of amyl, valerianate of amyl, sebacylic ether, oxalic ether, and amylic ether. Few of these have been found to be of any practical use except the amyl compounds, which are formed by the action of various acids, as formic, acetic, etc., on amyl alcohol (fusel-oil) and distilling in the presence of sulphuric acid. These compound ethers have proved to be exceedingly useful in making pyroxylin varnishes, as they are non-hygroscopic and flow out perfectly, dry readily, and are not injurious to the health of the workmen. Acetate of amyl has been most largely used and is at the present time in such demand for this purpose that the supply in this country and Europe does not nearly reach the requirements; while a few years ago fusel-oil, from which it is made, was a waste product of the alcohol distilleries, for which it was difficult to find disposal. Unfortunately no practical way has yet been invented for making the amyl compounds synthetically, and it is impossible to obtain them except from a by-product; so a shortage is a natural result.

Cellulose.—Another important question to decide is what form of cellulose shall be used to give a certain result; many are used, such as cotton, both in the fibre and as cotton waste, etc., straw, pith, flax, paper, ramie, etc.; the choice among these has its own influence; and even the thickness of the fibre will cause one lot of cotton to entirely disintegrate in the acid mixture, while a different fibre will nitrate and remain as strong as the original.

Nothing but these pyroxylin lacquers has successfully answered the requirements of the enormous factories which turn out building hardware, gas and electric fixtures, lamps, all sorts of polished brass, silver and silver-plated articles, all of which easily tarnish and must be protected.

Colored Lacquers.—These lacquers are also colored by dissolving various dyes in the pyroxylin solution, and are then used for decorating metals and glass; the largest use of these colored lacquers is probably for coloring electric-light bulbs.

Enamels.—Beautiful enamels are also made by grinding pigments in these varnishes; some difficulty is experienced with heavy pigments, which are hard to keep in suspension; but the lighter ones will remain a long time without settling. Velvet blacks are especially used on ornamental metal work; also gray colors are coming into use.

Resins Used with Pyroxylin.—Pyroxylin varnishes are greatly improved for use with the brush by adding to them various resins, such as shellac, manila, sandarac, damar, mastic, tolu, benzoin, etc. These give an increased body to the solution without increasing its viscosity and thus enable us to get a heavier coating without changing the flowing qualities of the varnish. The most serious difficulty experienced with these solutions is due to the fact that most resins contain acids, and these cause the film to decompose so that a polished metallic surface is liable to darken after a week or so, which is a fatal objection.

Thin Films.—The great desire of the pyroxylin-varnish makers has always been to get an article which could be applied to wood in such a way as to compete with oleo-resinous varnishes and paints; the great difficulty has been that when pyroxylin solution is made up to the consistency of these varnishes, there are only about six ounces of pyroxylin to a gallon of solvent; when the film dries the solvent evaporates, and the amount of solids remaining is so small that there is an exceedingly thin film, thus requiring many applications to get a sufficient covering; while with the oleo-resinous varnishes the contents which become solid on drying amount to three or four (or more) pounds to the gallon and the thickness of the film is correspondingly greater.

Fillers.—The best results in the use of these varnishes on wood have been obtained by using a pyroxylin solution for a filler which lays the grain of the wood exceptionally well, then applying an oleo-resinous varnish over this for body, and finally a finishing coat of pyroxylin varnish for hardness. This method of procedure has been used very extensively in finishing pencils, penholders, rulers, hair-brushes, and all sorts of small wood articles. Oleo-resinous varnishes require either long drying or baking, while the quick drying of the solvents makes the pyroxylin lacquers more desirable for some of this work, especially as they produce a surface of unusual hardness and durability.

Thinness of film, i.e., a lack of a sufficient amount of binding material, prevents making paints for ordinary use; but 10 per cent., or thereabouts, of pyroxylin solutions has been added to linseed-oil paints with good results, and many large paint manufacturers are experimenting on this line.

Artificial Leather.—Great interest has been manifested in the problem of applying pyroxylin solutions to leather to avoid cracking the enamel, which is so great a disadvantage of the ordinary patent-leather finish.

It is now used in large amounts by patent-leather makers, making the leather tougher and more water-proof, and greatly improving the quality of the finish. It is used as the base of the imitation leather which consists of a filling and finish applied to some strong textile material, and which is thought by many to be better and more durable than genuine leather. It is used in furniture and carriage finishings; and in some instances for wall decoration and similar uses. These imitation leathers may be embossed and colored, are waterproof and sanitary, and wear well. The pyroxylin solution is mixed with oil, oxidized or otherwise thickened, and other materials, so as to give a substantial body to the fabric, but the essential and characteristic thing is the pyroxylin.

One of the best-known uses of pyroxylin lacquers is its use as a medium for applying bronze and aluminum powders; amyl acerate, which is the chief solvent, has a pungent odor resembling bananas, hence the lacquer used for these bronze and aluminum paints has the trade name of "banana liquid." In this way the use of pyroxylin varnish is becoming generally familiar.

Not cellulose nitrate only is capable of being used as a varnish; the tetracetate of cellulose is prepared by the action on cellulose of glacial acetic acid, and this is soluble in certain volatile solvents, one of which is tetracetate of carbon. Films of this material are practically fireproof; at least they are not readily inflammable. Unfortunately this is much more expensive than cellulose nitrate; but the increased cost is warranted when the fire-risk is high, as in moving-picture films.

CHAPTER XIV.

OIL PAINTS AND PAINTS IN JAPAN.

PAINT has been used for decorative purposes from prehistoric times, and is so used at the present day by all savages as well as all civilized races. That which makes paint decorative is its color, and this comes from the pigment which it contains. Pigments are solid substances, insoluble in the oil or other liquid which forms the fluid part of the paint (and which is technically called the "vehicle"), and are in the form of a fine powder, usually reduced to the desired fineness by grinding, but sometimes, as in the case of lampblack, chemically deposited in a form so finely comminuted as to satisfy the needs of the paint manufacturer.

Fineness.—In general pigments should be so fine that they will pass through a brass wire sieve having two hundred meshes to the linear inch; for some uses pigments may answer which are not so fine, but in any case should pass through a screen of one hundred meshes to the linear inch. In preparing these, the substances of which they are to be made are ground in burr-stone mills, sometimes dry, sometimes mixed with water; in the latter case, they may be sifted wet, but more commonly are dried, crushed, and bolted. The bolting process is also applied to dry ground pigments. But for cheap paints it is assumed to be safe to determine by trial how the mills should be arranged and then put the material through and use it as it comes from the mill without any preliminary sifting or bolting. The paint manufacturer who buys the prepared pigment has his own methods of testing for fineness; the most common thing is to rub it on a glass or porcelain plate with a palette-knife side by side with a standard article. Practically nearly all selection of pigments is by testing them against standard articles, chemical analysis being only occasionally resorted to, and then for impurities in well-known chemical substances, such as white lead.

In testing a pigment for fineness on a wire sieve, it is common to try to get the last portion through, as nearly as possible, by brushing it with a camel's hair brush to break up any lumps of fine particles which may tend to stick together.

It is also a common method to wet the pigment with water and then wash it through a piece of silk bolting-cloth, using a jet of water from a wash-bottle. The grade of cloth is usually No. 21 Standard (not 21 special) which has about 175 meshes to the linear inch; but the threads are larger than wires, and are somewhat fuzzy as seen through a microscope; and the effective openings are probably about like a 250- to 300-mesh wire screen. In the manufacture of some pigments, such as white lead, it is commercial practice to wash the whole of the finely ground product through such cloth; the cloth is preferred to wire because it does not rust or become destroyed by the chemicals used in making the pigments. In the course of time and use the threads become smaller and smoother, and the openings consequently larger; but silk bolting-cloth is expensive, so it is used as long as possible. To overcome the objection of its increasing openness it is often the practice to put the sifted material through a second cloth, the latter being newer; but, of course, this also becomes worn, and before the old cloth is replaced by this newer one there is a period when material will pass which will be rejected on a new test-piece. In order to be fair it is therefore common to specify that when washed through a piece of new No. 21 bolting cloth not more than a certain per cent. may be too coarse to go through. To be in accord with the factory practice this should probably be about 2½ per cent.; but specifications often say ½ of 1 per cent.; which is, in the opinion of the writer, absurd, if it is only intended to say that the manufactured product shall be equal in fineness to one made in the manner just described.

If we consider only the diameter of the particles, which is probably what we should consider, an allowance of 2½ per cent. corresponds to an increase in coarseness from 200 to 195 per linear inch, which is not a large allowance for wear.

The only way to test the absolute fineness of such particles is by the classifier invented by G. W. Thompson, and described by him in the Proceedings of the American Society for Testing Materials, Vol. X., 1910. In this apparatus the particles of different sizes are separated. The average size of the larger ones may be microscopically measured, and that of the smaller may be computed by using formulæ known to physicists.

Attempts have been made to arrive at some conclusions along this line by weighing a standard volume—usually a cubic inch—of a dry pigment. Obviously, those of different specific gravity, e.g., red lead and iron oxide, will differ; but it is also found that different samples of the same kind of a pigment also differ; thus, a cubic inch of a certain sample of red lead may weigh only 15 grams, and of another sample 30 grams. It has been assumed that the more bulky material is the finer. If the pigment consisted of spheres, it is obvious that it would make no difference in weight whether these were all one-thousandth or all one-ten-thousandth of an inch in diameter; but a mixture of the two would be heavier, because the smaller ones would occupy the spaces between the larger ones. Hence the apparent density of a cubic inch of coarse particles would be increased by adding some fine ones; and exactly this thing may in some cases be done with pigments; that is, we may have a coarse grade which is of a certain weight per cubic inch, and a fine grade of the same weight, and a mixture of the two is heavier. This is equivalent to saying that a coarse pigment may be made to weigh more per cubic inch (dry) by pulverizing it partly, and this will be true if the particles are originally all about alike. This is easily understood, but it is not so easy to understand why, if we take a red lead which weighs 15 or 20 grams per cubic inch and grind it in a mortar or in a pebble mill (a porcelain cylinder partly filled with quartz pebbles or porcelain balls, and revolved slowly), the product of this regrinding will weigh

30 grams per cubic inch; which will usually happen. There must be reasons for such things, but we do not know them. It is certain that such an apparatus is of little value in comparing products of different origins, but where a pigment is always made in one way, from one kind of stock, it may indicate the presence or absence of a desired degree of uniformity of some kind in the product. It is, moreover, possible for an experienced operator to vary the results with the same material 10 per cent. or more either above or below the normal, by skilful manipulation. An instrument which gives results varying 20 per cent. at the will of the operator is not one of scientific accuracy.

As has been said, the Thompson classifier is accurate; and within limits the sieve is also absolutely accurate.

It is not the purpose of the writer to go into any elaborate account of the various pigments because there are now books devoted to that subject which treat it more fully and with greater knowledge than he can. But the action of pigments on the vehicles or liquids in which they are mixed is a proper subject to consider here, and while it cannot be discussed in a very thorough manner, it is desired to say something about it, and it is desirable to first say something about the most common and important pigments. All very light colors have white as their foundation or principal ingredient, and white pigments are limited in number to a few substances, the chief being white lead and white zinc.

White Lead.—White lead, when made by what is known as the Dutch process, as most of it is, consists of a mixture of two or three parts of carbonate and one part of hydrate of lead. It is made from metallic lead, which is cast into plates of irregular form, a few inches in diameter, termed "buckles," which are arranged in earthen jars over dilute acetic acid and kept in a warm place where they will be exposed to air containing a large amount of carbonic acid, usually by burying the jars in fermenting tan-bark. The acid attacks the lead, forming acetate of lead; this is decomposed by the carbonic acid, making carbonate, and the acetic acid set free attacks a fresh portion of metallic lead, and so on. The Bolognese MS., written early in the fifteenth century, gives the following formula: "Take lead in plates and suspend them over the vapor of very strong vinegar in a vase, which after being luted must be placed in dung for two months, then scrape away the matter that you will find upon the plates, which is the white lead. Do this until the plates are consumed." So that the process has remained unchanged at least five hundred years, perhaps five times that. In fact, an almost identical formula is given by Dioscorides, in the first century B.C.

White lead is supposed to have the formula $2PbCO_3.Pb(OH)_2$, but in practice the proportion of hydrate is somewhat variable; the formula calls for 68.91 per cent. $PbCO_3$ and 31.09 per cent. $Pb(OH)_2$; but if the action of the carbonic acid is prolonged the hydrate is converted into carbonate, so that it may be as low as 25 per cent. In current American practice the pig lead, which is specially refined, is cast into round flat perforated plates about 5 ins. in diameter and $\frac{3}{16}$ in. thick, which are called "buckles" and weigh about a pound each.

These are put in earthen corroding pots, 10 ins. high and 6 ins. in diameter, the lower 3 ins. being smaller than the cylindrical upper part (so the buckles will not enter) and this lower part is glazed within, to hold the weak acetic acid used. About half a pint of 2½ per cent. acid is put in each pot, and then the upper part is completely filled with buckles which lie horizontally, one on another. Only cast lead is used; if the buckles were stamped out of sheet lead the metal would be too compact and would not corrode well.

The building where the corroding is done is called a stack building, and is divided into rooms, or stacks (so called because the pots are stacked one on another), which stackrooms are of various sizes, frequently about 20 by 40 ft. in area, and about 30 ft. high. At first a layer of tan-bark about 20 ins. deep is placed on the floor; then on this a layer of corroding pots, which are then charged with acid and buckles, except a margin of about 15 ins. around the edge of the surface, which is packed with tan-bark, and known as "banking." Boards are laid on top of these pots, and on this false floor another layer of tan-bark about 15 ins. thick, then a layer of pots as before which are charged with acid and lead buckles, and then another layer of boards, and so on until the stack is completed, containing ten or twelve layers. Some means are taken to ventilate the different layers, the most common being a wooden flue running from each tier up near the centre of the stack to the top, where it may be opened more or less as may be desired.

The tan-bark undergoes a slow combustion, apparently a fermentation. At all events, the temperature rises sometimes to 160° or 180° F., and carbonic acid is given off abundantly. In presence of the acetic acid vapors and carbonic acid the metallic lead is converted first into basic acetate of lead and then into basic carbonate, which is the pigment. This takes from ninety to one hundred and twenty days. Then the tan-bark is removed and used again to build another stack, while the pots are emptied of their contents, which consists of white lead and some uncorroded metal.

Machinery is used for mechanically separating these, and the white lead is finally ground in water in burr-stone mills, after which it is floated to separate any heavy particles, such as metallic lead, and finally allowed to settle in settling-tubs. From these it may be pumped into great copper steam-jacketed drying pans, or it may while still wet be mixed, in suitable mechanical mixers, with oil, which has a greater attraction for white lead than water has and will displace it, leaving less than ½ per cent. of water in it; such lead is preferred by many as being softer than that which has been dried by heat.

White lead is also made in three large factories by the Carter process; in which the melted lead is allowed to trickle into a jet of superheated steam, by which it is "atomized" into small spherical particles. In this condition it is put into large horizontal wooden cylinders, which may be made to revolve and thus agitate the contents. Diluted acetic acid and water are from time to time sprayed into these cylinders, and carbonic acid, obtained by burning very pure coke, and purified, is caused to pass through them; in about twelve days the lead is nearly all converted into white lead, which is then washed, floated and otherwise treated as already described.

Another very similar process known as the Rowley or "mild" process, is in practical use; in this the lead is sprayed or "atomized" into very fine particles, the aim being to make it as fine as possible, so that it will mix with water to form a pulp or mud, which is a condition avoided in the Carter process. This is put into revolving drums, wet, and air blown through, no acetic acid being used. The lead is oxidized under these conditions, yellow hydroxides being formed; these are carbonated by finally blowing carbonic acid through the agitators. In this way white lead is the product obtained.

Still another way of making white lead is by a precipitation process; the metallic lead is treated with dilute acetic acid in large wooden tanks, forming basic acetate, which is then treated with carbonic acid gas, until a basic carbonate is formed. This is known as the Matheson process, a modification (as to details) of the old French or Thénard process, which is said to have gone out of use in France, but has been improved and made practicable here.

White lead is made in Europe by the Chamber process. The lead is cast in strips several feet long; then these are hung on wooden racks in a closed chamber, and air, steam and carbonic acid are blown in, until after the lapse of considerable time the lead is in considerable part converted into white lead. The subsequent treatment is as in making Dutch process lead. It is said by Petit that this lead is less opaque than Dutch process lead, which latter is preferred, although not quite as white.

There is also said to be a method of making it in Russia from litharge, on the floor of a closed chamber, where it is turned over with shovels, by hand; a very unsanitary process.

Lead Poisoning.—So much has been written about this that a few words from one who has first-hand knowledge is perhaps of interest. Since phosphorus poisoning has been obliterated, this is of all industrial diseases the easiest to talk and write about;

and as a rule the young person who has decided to become a sanitary expert begins by having a great deal to say about it. In New York State, with about nine million population, one or two cases of death from this occur yearly; so that, so far as statistics go, it may be said to be negligible. It is well known by mechanical superintendents that the best safeguard against accidents is intelligence on the part of the workman; it is equally true that the only absolute safeguard on the part of the worker in lead is reasonable care and cleanliness. As for the horrifying stories of helpless sufferers—well, I don't feel any interest in them. So far as I have seen the managers and superintendents of the lead factories do not wish their men to be lead-poisoned; and if any one is, it is because he violates the rules; and especially the rules which ask for ordinary and decent cleanliness. Lead is not poisonous as applied to the skin; lead plasters and washes have been used externally for hundreds of years. But any lead compound taken into the stomach is dangerous; and only in the alimentary canal is it so. Dust containing it, inhaled, gets from the nose into the throat, and in this way is dangerous; and it gets into the body and stays there; it is cumulative. Ignorant and careless men get it in their mouths with tobacco, and by eating with hands dirty with lead compounds; from their beards and moustaches the way to the mouth is short. In these days when a man has any sort of illness, no matter how trivial, the company's doctor pounces on him without notice or delay; and if he is lead-sick he is at the same time treated and lectured. Then if he is incorrigible he is discharged—" fired "— from the employment, or put at work where he cannot hurt himself. The people who suffer most are the journeymen painters, who are difficult to teach and in fact difficult to reach, though the master-painters as a rule try to get after them. I have never known a master-painter yet who believes that lead-poisoning is in practice a serious matter.

The large modern factories take great care of their men; they have ample washing facilities, hot and cold water, soap, towels; shower-baths equal to many an athletic club; dining-rooms, rest-rooms, sunny and sanitary; a capable physician looks them over every few days; and the superintendents and foremen are watching them all the time. There is such a thing as lead-poisoning, or these things would not all be done, but 99 per cent. of the talk about it consists of words without knowledge; and it is always the result of carelessness on the part of somebody.

If a considerable amount of lead salt which is soluble in the stomach is swallowed, it acts as an irritant poison, but fatal results are not to be feared in such cases. The absorption of a little every day for a long time is dangerous, producing sometimes partial paralysis, and even death. Men unacquainted with the need of precautions are sometimes attacked with "painter's colic," painful but not dangerous; it resembles a severe case of indigestion, and if it is taken as a warning and better habits adopted no harm is done; but if its nature is not appreciated it is dangerous as being the first sign of the presence of lead in the system. People may be lead-poisoned by the most gradual and insidious stages, which is the reason they should be examined frequently by an expert. But it is absolutely preventable; and so rare, compared with other diseases, that it can hardly be a subject of much apprehension.

White lead is not the only white pigment made from lead. The most important ore of lead is the sulphide, a heavy blue-black mineral called galena; this may be put into a suitably constructed furnace with some coke or other fuel and burned; the sulphur oxidizes and sulphate of lead is formed. The operation is not as simple as this statement implies; the product is in fact a basic sulphate and is often said to consist of $PbSO_4$ and PbO in varying proportions. But this again is more than doubtful; PbO is litharge and there is apparently no litharge in it. It is probable that there is some $PbSO_4$ and some of a more strongly basic sulphate. The amount of this basic lead, which is often expressed as PbO, is from 1 or 2 per cent. to 30 or 35 per cent. It is possible that this may be influenced by the condition of the air at the time of burning; the presence of a high proportion of moisture in the combustion chamber may reasonably be supposed to have an effect different from that which is brought about when the air is relatively dry. These considerable variations in composition have less effect on its value as a pigment than would be expected. It was at one time hoped that this basic sulphate might be less poisonous than true white lead; but this does not prove to be the case. This is sometimes called "sublimed white lead," which would imply that it is white lead made by sublimation; which, of course, is not so, and in fact the use of the name white lead is prohibited in England for this product. But this is of small account; the material is used as a substitute for white lead in mixed paints and is a valuable pigment. It is extremely fine.

What is called "sublimed blue lead" is an off-colored sulphate, made from the fumes from reducing ore in "Scotch hearths" and is a sulphate colored with soot (lampblack) and some sulphide.

White Zinc.—This is zinc oxide, ZnO, and is made by burning zinc in a current of air. French zinc, or French process zinc, is made by burning metallic zinc; American zinc, or American process zinc, is the slightly impure oxide from burning zinc ore. The latter is less expensive but just as good except where extreme purity of color is desired. The best French process zinc is a very white pigment; less purely white than the whitest plaster of Paris, but whiter than white lead. All white zinc is very fine, but there is difference in it even in this respect, as the finest and whitest is said by Petit to be separated by air-floating.

Zinc paint is harder and less elastic than white lead; it often shows a tendency to peel, and this is said to be one of its defects. It does not always do so, and it is but reasonable to assume that when it does it is due to some defect in the undercoat, or, more likely to wrong proportion of oil and pigment, or lack of skill in its application; for if it stands well sometimes it should do so always. It cannot well be denied, and is admitted by those who advocate its use, that it does not work as easily or have such good flowing quality as white lead; but on the other hand it does not as easily become yellow in the dark. All white paints, indeed all white objects of organic origins, tend to become yellow in the absence of light; white lead paint in the light is bleached constantly, but in the dark yellows somewhat; white zinc does the same, but its yellowing in the dark is much less. It is, as has been said, whiter than lead. More care is necessary in selecting oil for white zinc; all oil is naturally slightly acid and rather highly acid oil is liked for lead, but zinc does not work well with acid oil.

Zinc has the quality of requiring much oil to make a paint of good working quality; about twice as much as white lead. The only reason which has been offered for this is its greater fineness; but this may not be the sole or even the principal reason. White lead is made into a paste by grinding 92 pounds of dry white lead with 8 pounds of oil, though less oil is sometimes used, as in what is called C. & C. (coach and car) lead. But 85 pounds of white zinc requires 15 pounds of oil; this makes a stiff paste. If this hundred pounds of paste white zinc is thinned with 6 gallons (trade gallons of 7½ pounds) of oil (=45 pounds) we have 145 pounds of paint measuring 9.62 gallons or 15 pounds per gallon; and containing 8.65 pounds ZnO and 6.22 pounds oil per gallon.

But this is rather heavy paint and is likely to show brush-marks when applied. It is more common practice to add to the 100 pounds of paste 7 (trade, or 6¾ measured) gallons of oil, =52½ pounds, making 152½ pounds of paint measuring about 10.6 gallons and weighing 14.4 pounds per gallon, containing 8 pounds ZnO and 6.4 pounds oil per gallon. If to this we add ⅔ gallons of spirit of turpentine, we have 11¼ gallons of paint weighing 14 pounds per gallon and containing about 7½ pounds ZnO, 6 pounds of oil and ½ pint of turpentine per gallon. This is a very good mixture. To this drier may be added as desired.

It is worth noting that G. Petit says white zinc paste contains 80 to 83 per cent. ZnO and 20 to 17 per cent. of oil; Paul Fleury says the Vielle Montagne Company, which practically controls the European manufacture, recommends 85 to 15. One of the best American grinders uses 84 to 16, some others 85 to 15. The more oil the softer the paste; no one appears to use less than 15 per cent. of oil.

White lead paste is commonly said to contain 10 per cent.

of oil; but the National Lead Company, which is by far the largest single white lead concern, uses about 8 per cent. with stack or Dutch process lead, Carter lead, or Matheson lead.

It is said that the Dutch process lead can be ground in 6 or 7 per cent. of oil. This the writer has never seen; samples said to contain 6 per cent. of oil have analyzed 8 per cent. or over. It may be, however, that a 6½ per cent. paste may be made in a chaser; it certainly cannot be made in an ordinary paint mixer. However, it is possible that this low proportion of oil is now only a tradition and that in former times when lead was much coarser than it is now it may have been done; for a coarse pigment needs less oil to wet it than the same material which is finer; and there is no question but that white lead is now much finer than it was twenty-five years ago. My own experience is that lead with only 6 per cent. of oil is a putty, rather than a paste; putty is plastic but not viscous, paste is viscous but not plastic.

The fluidity and working quality of white zinc paint are considerably increased by age. In making enamel paints the pigment is ground in enough vehicle to make a rather soft paste, which is aged for six months and then reground with enough varnish for use. The same may be done with oil, but it is better to grind it with the full amount of oil in the first place. It should be aged two months if possible, though a week or two makes much improvement. The opacity of white zinc is probably about the same as that of white lead; that is, a pound of zinc oxide (ground in a proper amount of oil) spread over say 3 sq. yds., will hide the surface as much as a pound of dry white lead, also ground in oil, applied to a like surface. But inasmuch as the zinc requires more oil it naturally makes a thinner coating and in order to get the whole of the pound of pigment on the limited area more than one coat must be applied. As a matter of practice three coats of white lead are reckoned equal to five of zinc; though, of course, this ratio is subject to variation either way. This behavior of zinc oxide toward oil indicates chemical action (or perhaps a surface action of a physical nature), and such action may be the cause of its requiring a large proportion of oil, rather than its excessive fineness; perhaps both are causes. It is generally true that finer pigments take more oil than coarse ones; but the nature of the pigment and its affinity to oil must be considered, as is shown by the fact that powdered silica takes more oil than equally fine barytes.

Lithopone.—This is a white pigment made by adding a solution of barium sulphide to one of zinc sulphate, making a precipitate of a mixture of zinc sulphide and barium sulphate, in the proportion of about 29 per cent. of the former of 71 per cent. of the latter. It is a white powder of fine color and unusual opacity, and is much used for a certain sort of paint. Practically all of it is used in making what is termed interior flat finish, for plastered walls; this has as a vehicle a rosin varnish, of which the oil ingredient is tung-oil, and which is thinned with a large proportion of "mineral turpentine." Neither white lead nor white zinc can be used with rosin, as they rapidly react together; but lithopone is inactive. Such a paint carries but little binding material, and a large proportion of pigment; hence, when it dries there is not enough varnish to make a full, glossy surface, and the "flat" or matt effect is liked as a wall finish; it can be tinted with other colors, but is generally used white or in some very pale color. When exposed to a strong light lithopone is partly decomposed, the oil or varnish probably acting as a reducing agent, and the zinc sulphide is in part changed into metallic zinc, a gray powder, so that the paint darkens or turns gray. Many patents have been taken out for making it stable, but none is more than partly successful; the zinc sulphide is essentially unstable; and partly for this reason, partly no doubt because of its large content of barium sulphate, this pigment is worthless for out-of-door use; paints containing it rapidly disintegrate when exposed to the weather. Interior finishes do the same, but more slowly; they become brittle, crack and peel after a time, which, however, may sometimes be four or five years. When new the best of them are very handsome and are easily applied.

Lithopone, unlike white lead and white zinc, can be mixed with shellac varnish, and is used on white mouldings, especially for cheap picture frames.

The chemical instability of lithopone, which is shown by its partial reduction under the action of light, is probably the reason why it is a failure when exposed to the weather. It is likely that sulphur acts on the oil in the film, making it brittle; it is known that all vegetable oils are easily attacked by sulphur; and this may, in fact, be one reason why the lithopone flat interior finishes often peel off. The most important cause of this, however, is probably the fact that the painter, from mistaken economy, tries to make a finished job with two thin coats; it is well known that a given amount of pigment shows most opacity when used with as little oil as possible; so in order to get the necessary covering power the amount of binder in the paint is reduced as much as possible, and such a film does not have enough oil in it to stick it strongly to the underbody. The way to remedy this would be to have a different composition for each coat, as is done in painting with white lead; enough oil in the first coat to penetrate any porous places, and to make a good binding coat; then use two more coats, the third, or surface, being quite flat. But this would cost more, and there would be little inducement to use it.

Auxiliary Pigments.—It has been said that white lead, white zinc, and in a limited class of paints, lithopone, are the white pigments used in paints. The other pigments which are white in the form of dry powders are nearly transparent when ground in oil. The most important of these are barytes and asbestine, besides which we have silica, white clay (China clay), whiting, gypsum, and, somewhat rarely, carbonate of barium.

Barytes is barium sulphate; it occurs as a white, more or less crystalline mineral, heavier than most minerals, and when cleaned from other substances it may be ground to a powder and used in paint. It is remarkable for requiring less oil to make a paste or a paint than any other pigment. If white zinc be mixed in certain proportion with barytes a pound of the mixture will require no more oil than the fraction of a pound of zinc would have needed if no barytes had been present. As it is a low-priced material, it thus increases the weight and volume without a corresponding increase in cost. Moreover, it increases the proportion of pigment to the unit amount of oil, which may be a desirable thing. White lead, which also has low oil-taking capacity, is in like manner added to white zinc; and although the barytes mixture is no doubt inferior to that, it is much cheaper. Many people think it is of not much consequence what the pigment is, so long as the oil is pure; a wrong notion, to be sure, but common. At all events, almost all barytes is used in this way to extend white zinc paint. Sulphate of barium is also made as a by-product in some chemical factories, and being a chemical precipitate it is a very fine powder, known as blanc fixe, but it is not essentially different from the powdered mineral. If raw linseed-oil be ground with barytes and allowed to stand, it is bleached, losing at least half its color; so that this pigment is not inactive toward oil; indeed, the singular fact that it takes less oil than any other white pigment implies as much.

Silica, even in the form of powdered quartz, is also able to bleach linseed-oil. It is used somewhat as an auxiliary pigment, but recent inquiry among several large paint manufacturers seems to indicate that its use is not extensive. It is largely used as a wood filler, before varnishing.

Next in importance to barytes, if not exceeding it, is asbestine. This is made by grinding a rock closely related to asbestos; in fact, if the crystals, or fibres, were longer and more distinct, it would be asbestos. It has a fluffy, somewhat fibrous texture when ground; takes more oil, weight for weight, than white zinc, and in this respect when mixed white with lead it has much the same effect that white zinc does. It may be regarded as holding a relation toward white lead and basic lead sulphate, analogous, though opposite, to that of barytes to zinc; that is, it is the natural auxiliary pigment. Barytes, as a pigment, is the opposite of zinc; so if zinc has any faults, the barytes may be supposed to correct them; and if lead has any faults, asbestine may do the like for it. This may strike the reader as rather fanciful; but it is in a large measure the theory on which the mixed paint manufacturer acts.

Asbestine not only takes considerable oil, but on account of its fluffy character and its low specific gravity it does not tend to settle badly, and is therefore used with basic lead sulphate, which is heavy and does settle. White lead is heavy, and though not bad about settling it does tend to do so, and asbestine is used with it also. In the inferior grades of mixed paints, which contain but little lead or zinc, asbestine is used to hold up barytes. Having a low specific gravity it is bulky, even when wet with oil; it takes much oil or other vehicle, which is generally cheap; and its price is low, so that it lowers the cost of paint in every way. It has nearly displaced China clay, which it resembles in chemical composition, because of its non-settling quality, in which is exceeds clay.

Powdered gypsum is known in the paint trade by the mysterious name of terra alba—white earth—and is the most nearly colorless and transparent pigment we have. For this reason it is used with bright colors, as it dulls them less than anything else. Aside from such uses it has very little place.

Whiting is powdered chalk, also known as Paris white, and is the finest, softest and perhaps the least transparent of any of the auxiliary pigments. Compared with some of the others it is not very cheap, but nearly all mixed paints contain a little of it. This is because of a traditionary belief that as it is a lime salt it corrects the acidity of oil. No one has ever proved yet that it does; and no one knows for sure that a little free fatty acid, such as is naturally present in raw oil, is any injury to the paint. I doubt if either is true.

Value of White Under-body.—These white pigments, zinc and lead, are the base of all light-colored paints, for it is impossible to make a light-colored paint out of dark-colored materials. They are also used to make a white foundation on which other colors are overlaid. This is a practice of great antiquity and is followed not only in the painting done by artists, but also in not a little technical work, using somewhat transparent colors over the white, which then serves as a sort of mirror, reflecting the light which penetrates to it outward through the translucent outer coat again, and thus producing a warm and brilliant effect to be had in no other way. Eastlake says that "it is an important fact in painting that a light, warm color, passed in a semi-transparent state over a dark one produces a cold, bluish hue, while the operation reversed produces extreme warmth. The secret of Van Eyck and his contemporaries is always assumed to consist in the vehicle he employed, but a far more important condition of the splendor in the works of those masters was the careful preservation of internal light by painting thinly, but ultimately with great force, on white grounds." This is not a new observation, though so true and important as to bear repeating. Aristotle made the same remark: "White surfaces, as a ground for colors, have the effect of making the pigments appear in greater splendor." Again Aristotle says ("De Sensu et Sensibi"): "Another mode in which the effect of colors is exhibited is when they appear through each other, as painters employ them when they glaze a color over a lighter one, just as the sun, which is in itself white, assumes a red color when seen through darkness and smoke. This operation also ensures a variety of colors, for there will be a certain ratio between those which are on the surface and those which are in depth." Compare this with Leonardo Da Vinci, on Painting, Chapter CCXXXIII: "When a transparent color is laid upon another of a different nature, it produces a mixed color, different from either of the simple ones which compose it. This is observed in the smoke coming out of a chimney, which, when passing before the black soot, appears bluish, but as it ascends against the blue of the sky it changes its appearance into a reddish brown." It might be inferred that Leonardo had read Aristotle, and no doubt he had, for he was a man of much learning and not only one of the greatest painters but also one of the greatest men who ever painted; but it is to be observed that not only the foregoing, but about every other important theorem on the subject, may be found in his book. In regard to the same thing Pliny (l. xxxv, c. 18) says of

Apelles: "No one was able to imitate one thing in that he spread the varnish over his completed work so thin that it brought out the brilliancy of the colors by reflection and protected it from dust and dirt. It seemed to the beholder to be directly from the hand of the artist. And this with good reason, for the brilliancy of the color could not offend the keenest eye, just like looking through a piece of mica from a distance, and this thing secretly gave darkness to the too-bright colors."

So it appears that there are both artistic and traditional reasons for the very general use of white (especially white lead) as a priming coat, and perhaps the tradition is a strong reason for the general belief in it, especially when its color will finally be of no effect.

Importance of Fine Grinding.—In this connection it should be pointed out that when it is desired to secure this brilliancy by superimposing colors on a light ground, their clearness must be greatly enhanced by having the pigments ground to the last degree of fineness. This was well known to the great masters in painting, who had them ground most carefully in their own laboratories. Cennini (ch. 36) says: "To grind properly, procure a slab of porphyry which is strong and firm. There are many kinds of stone for grinding colors, as porphyry, serpentine, and marble. The serpentine is a soft stone, and is not good; marble is worse, that is, softer; porphyry is the best of all, and if you procure a slab very well polished, it will be better than one with less polish. Take another stone, also of porphyry, smooth on one side, and raised on the other, in the shape of a porringer and half the height of one, of such a form that the hand may hold and guide it at pleasure. Then take some of the color and put it on the slab, and with that stone which you hold in your hand break the pigment into small pieces. Put some clean water, either from a river, a fountain, or a well, to the color and grind it well for half an hour, or an hour, or as long as you please; but know that if you were to grind it for a year, so much the better would be the color. Then take a flat piece of wood, part of which is pared thin like the blade of a knife, and with this blade collect the color neatly; keep it liquid and not too dry, that it may flow well on the stone and be thoroughly ground; then collect it carefully. Put it then into a small vase and pour water on it till the vase is full, and in this manner keep it always soft and well covered from the dust, and from all other dirt, that is, in a little box adapted to hold vessels of liquor." Again, when speaking of vermilion, he says: "Put this then upon the slab above mentioned, grinding it with clean water as much as you can—if you were to grind it for twenty years, it would be but the better and more perfect." No care was too great for the proper mechanical preparation of pigments, in his opinion; note the use of the wooden palette-knife, to avoid contact with iron—a very general precaution. And after giving long and elaborate directions for preparing ultramarine (the natural, not the artificial), he adds: "You must know also that it (the care of preparation) is rather the acquirement of youth than that of men, because they remain continually in the house, and their hands are more delicate. Beware especially of preparing it in old age." Again and again he insists on having the best materials; thus in ch. 96: "It is usual to adorn walls with gilded tin, because it is less expensive than gold. Nevertheless, I give you this advice, that you endeavor always to use fine gold and good colors, particularly in painting representations of Our Lady. And if you say that a poor person cannot afford the expense, I answer that if you work well (and give sufficient time to your work) and paint with good colors, you will acquire so much fame that from a poor person you will become a rich one, and your name will stand so high for using good colors that if some masters receive a ducat for painting one figure, you will certainly be offered two, and your wishes will be fulfilled; according to the old proverb, good work good pay. And even should you not be well paid, God and Our Lady will reward your soul and body for it." Such are the opinions set down in the oldest treastise on painting; though six centuries old, they are worthy of remembrance.

Chrome Yellow.—The more important of the yellow pigments are chrome yellow and cadmium yellow. The chrome yellows are made in three shades, pale, medium, and deep. Of these the latter is, or should be, pure chromate of lead. It is orange in color. The medium chrome is the same with some carbonate or sulphate of lead, and the pale has still more of the carbonate or sulphate. The chromate is a chemical precipitate, and in making the lighter shades carbonate or sulphate of lead is precipitated at the same instant, thus securing a more perfect mixture than can otherwise be had, and more brilliant color. The chrome yellows when exposed to the weather are somewhat inclined to fade, but they are colors of great beauty and are very opaque. Some of the ochres are yellow also, but not so pure a color; they are, however, permanent, and are extensively used, especially in mixtures. Cadmium yellow is both brilliant and permanent, and is an excellent paint where the cost does not prevent its use; but it is expensive. The chromate of strontium is a pale yellow of great brilliancy, but transparent, so that it can be used only as a glazing color, usually over chrome yellow; it is of the highest degree of permanence. Yellow is not infrequently added to dark colors to give them a warm tone, and is often present in considerable amount where the untrained eye does not detect it at all. It has a most agreeable effect in these mixtures.

Chrome Green.—The most important green is chrome green, which is a mixture of chrome yellow and Prussian blue, the latter being chemically a ferrocyanide of iron. Each of these pigments has great coloring power, and their mixture is unsurpassed in opacity except by some of the blacks. The different shades of this color are made in the same way as the chrome yellows.

Paris Green.—A much more transparent color, but of extraordinary brilliancy, is Paris green, as it is called in this country, known as emerald-green in England, and by various names in Germany. It is an aceto-arsenite of copper, and not a very satisfactory paint, but it is of unequalled color, which insures a considerable use.

Chrome-oxide Green.—There is another kind of chrome green, namely, the green oxide, which is prepared both in the hydrated and the anhydrous state, the latter being preferred on all accounts. It is one of the most permanent and indestructible of colors, and is quite opaque, but rather dull in color. It is often said that this is the only pigment to which the name of chrome green should be applied, but in fact the name is appropriated commercially by the chrome-yellow-Prussian-blue compound, and in this country, at least, it has been found prudent to designate the other as chrome-oxide green. It is rather expensive and not brilliant in color, but of a color which, though rather cold, is considerably liked. It is a very valuable pigment. Zinc green and cobalt green are the same, a compound of zinc and cobalt, of fine color and extreme permanence. Its cost is the only objection to it.

Blue Pigments.—Only two or three blue pigments are in common use: Prussian or Chinese blue, a chemically prepared ferrocyanide of iron, a dark blue pigment, not very opaque, not extremely permanent; and ultramarine, a color originally had from a mineral—lapis lazuli—but now made artificially in great quantities. This is moderately permanent, not very deep in color, and constitutes most of the blue used in ordinary paints. In one respect it is an exception to a general rule, in that it is not improved but rather injured by excessive grinding. It is as though the color were on the outside of the particles as they come from the ultramarine manufactory and as if, on grinding, these particles were broken up and the color injured by bringing into view the interior portions of the particles.

Cobalt blue is a compound of cobalt and alumina, a fine color of the highest permanence, but rather costly. It is used to some extent for high-class work, but is rather to be regarded as an artist's color.

Vermilion.—No doubt the most important of the red pigments are the iron oxides, but as these are not pure in color, we may first mention vermilion, which is an artificial sulphide of mercury, of a beautiful scarlet color; it has always been, in spite of its rather high price, a favorite pigment; it is not very permanent. It is known in this country as English vermilion, most of it being imported from England; formerly it was called Chinese vermilion but that which comes from China does not appear to be equal to the English. What is known as American vermilion is made by precipitating red coal-tar colors on red lead, orange lead, or barytes, or on sulphate or carbonate of lead, and there are a large number of reds used in the paint trade which are made from the coal-tar dyes, some of which, unlike American vermilion, are very fast to light, but they are not of great opacity, being rather to be classed as lakes. It may be remarked for the benefit of such readers as are not familiar with these matters that lakes are compounds of the coloring matters of dyes with a mineral substance, such as lead or alumina; one of these, formerly much used, being carmine, made from cochineal, a very beautiful red substance, which has now been almost entirely displaced by coal-tar lakes; partly because of its cost, and partly because it is not permanent.

It should perhaps be added that there is a red basic chromate of lead which is also called American vermilion by some; also called Persian red and by various other fancy names.

Red lead is also used, but the consideration of this substance will be deferred to a later chapter, since it is chiefly used as a protective paint for iron and steel. The iron oxides are also so used, but their chief use is in making cheap paints for wooden surfaces, for which they are well adapted. Most of them are quite permanent in color; and though dull, they are of rather pleasing colors, and have great covering power or opacity. There are essentially two kinds of iron oxides, the anhydrous sesquioxide and the same hydrated. They exist in nature, the first as the mineral called hematite, the second as limonite. The former when powdered is dark red, the latter yellowish red. There are indeed other oxides of iron, notably the magnetic oxide, which is black in color, but it is not used as a pigment.

Hematite occurs pure in large deposits, and is worked for the manufacture of iron; the same is true of limonite. Hematite is, when a compact rock, hard and tough, and it is difficult to reduce it to such a degree of fineness as will be suitable for a pigment; the deposits of this ore which are softer and less compact are almost always mixed with limonite. The latter is more easily worked than the former and is also more abundant. The great supplies of iron-oxide paints are mixtures of these, and are found in deposits where the ore is in granular or earthy form, usually mixed with more or less clay; sometimes the clay amounts to two-thirds the weight of the whole, not uncommonly one-half. Such a material is easily reduced to a powder; it is roasted in furnaces to drive off the moisture and to develop a color, then ground dry. The author once operated one of these mines; though it was of exceptional character, a short description of the work may be of interest.

Iron Oxides.—The ore was ferrous carbonate, which had been brought to the surface by chalybeate springs and deposited in beds which were overlaid by a deposit of peat, the reducing action of which preserved the ferrous carbonate from oxidation. It was consequently a natural chemical precipitate and of extreme fineness as well as purity. When this carbonate of iron, which was nearly white in color, was exposed to the air it was rapidly oxidized into the ferric compound; it was put while still moist into a roasting-furnace, where it was heated in contact with air and the carbonic acid driven off; the residue being, of course, ferric oxide. By varying the heat and the amount of air different colors were obtained, from a fine yellowish red to a dark purple, the latter being the pigment known as crocus. The deep, strong red of Indian red was to be seen and the dull brown of ordinary oxide paint. These colors were all to be seen in the same charge, some lumps being of one color and some another; the whole was run through a mill, not to really grind it, for it was too fine for that, but to crush the agglutinated lumps, and it came out a mixture of tolerably uniform color, whose homogeneous appearance never would suggest the fact, so obvious to the operator, that it was composed of oxides of many different degrees of hydration and perhaps of oxidation. The lesson to be learned is that it is impossible to tell from the looks of such a paint what it is made of, and that it is not impossible for a paint containing a large percentage of iron oxides to have other and deleterious ingredients, since the strong and dominating quality of the oxide may overshadow and conceal everything else. This is without doubt a considerable reason for the difference of opinion, about the value of oxide paints, which exists. The greater part of these paints in this country is used for painting freight cars; not a little of the finer qualities, such as those oxides known as Indian and Tuscan reds, for house-painting and passenger-cars. Quite a large amount is also used on steel bridges, chiefly in the Western States, but its use for this purpose is less than formerly.

A large amount of the better grades of iron oxides for paint is imported from England and Germany. These are made, not from minerals, but as by-products in chemical work, one of the most common being the oxide left from the distillation of sulphate of iron in making fuming sulphuric acid. The cheapest way to dispose of this is to mix it with powdered chalk, or with milk of lime, to absorb the sulphuric acid remaining in it, which is thus converted into sulphate of lime. The pigment known as Venetian red is made in this way and contains a large percentage of sulphate of lime. Reds may also be made by washing and roasting these residues, and some of these are of excellent quality. No colors are more permanent than some of these pure oxides. They have lasted for thousands of years and there is no reason why they should ever change, except when they are subjected to somewhat unusual chemical action. Such a statement does not, however, apply to the impure oxides and especially it does not apply to the impure hydrated oxide. It does apply to the pure anhydrous and sometimes to the partially hydrated oxide when used as a paint on wood or some neutral base, and protected either by its situation or by oil and varnish from access of corrosive gases or liquids. Under such conditions, as, for instance, on the walls of houses at Pompeii, it seems absolutely permanent, keeping its brilliant color; but although it is a native mineral and it is evident from the great quantities which are found that it is a compound of great stability, it should not be assumed to be absolutely the most stable compound of iron, incapable on that account of change, as we may think is the case with barytes, for instance.

Iron Oxides not Absolutely Permanent.—So accurate and conservative an authority as Watt's Dictionary of Chemistry says, speaking not of the comparatively unstable hydrate, but of the anhydrous sesquioxide, that "even at ordinary temperatures it frequently acts as an oxidizing agent in contact with organic matter, and is thereby reduced to magnetic oxide, or even to ferrous oxide, and then, by taking up carbonic acid, converted into spathic iron; the reduced oxide, if in contact with moisture, is frequently also reconverted into ferric hydrate by atmospheric oxidation. The oxide is also sometimes further reduced by the action of sulphydric acid and converted into pyrites."

The same authority also says of the hydrated sesquioxide that it "easily gives up part of its oxygen to oxidable bodies and is easily reduced by sulphurous acid, etc. In contact with putrefying organic bodies, out of contact with air, it forms ferroso-ferric compounds, or ferrous carbonate, but if the air has access to it, it quickly recovers the oxygen which it has given up, and can then again exert an oxidizing action, thus acting as a carrier of oxygen from the air to the organic body; hence it accelerates the oxidation of woody fibre in the soil."

It is evident from the foregoing that, although, as has been said, under favorable conditions some of these oxides are among the most permanent of paints, their value depends on the conditions under which they are used. It is also not to be forgotten that when we speak of permanence in a paint we, perhaps unconsciously, assume the standard to be the paintings on canvas or the fresco painting on the interior walls of churches and the like, in all which cases the paint has been most carefully preserved and under favorable conditions.

The relative values of paints exposed to the weather might be quite different; in fact, such is the universal experience.

There is, however, no reasonable doubt that some of the iron oxides are valuable paints. Some of them are prepared from deposits of iron oxide mixed with clay, what might be called an iron-bearing clay if we remember that the iron is probably present, not in chemical combination with the clay, but as intermixed oxide; in these deposits the iron is in a finely comminuted condition, and these ores are easily worked and easily ground, and the resulting pigment is much less liable to rapid settling out of the oil or other vehicle than is the heavier pure oxide. It is possible that some of these clays may be so roasted as to become, like brick-dust, incapable of uniting with water; but if not, they obviously are a source of weakness, and in all cases are to be regarded with a reasonable amount of suspicion. There is, indeed, reason for suspicion of cheap materials of every sort, not because cheapness is an objection, for, of course, it is not so, but in fact a merit, but because it is apt to blind the eyes of the purchaser to such defects as the material may really have.

Iron oxides are also important constituents of some of the brown pigments, the most important of which is the earthy material called sienna, from the Italian locality whence it is obtained. This is of a beautiful red-brown, and is the pigment used to make stains to match mahogany. Umber is a much darker earth; both are still further darkened by roasting, when they are known as burnt sienna and burnt umber. Both are said to contain some oxide of manganese, and umber contains enough to enable it to impart a decided drying quality to oil.

Bone- and Ivory-black.—The black pigments are various forms of carbon. Bone-black or ivory-black, lampblack, and graphite are the principal sorts. Bone-black is made by calcining bones without access of air; the organic matter contained is decomposed and the oxygen and hydrogen are mostly driven off, the carbon being left with the phosphate and carbonate of lime of the bone. Ivory-black is made in the same way from ivory chips; but probably most of the ivory-black now sold is a fine grade of bone-black. This contains about 10 or 12 per cent. of carbon, to which it owes its color, 3 or 4 per cent. of carbonate, and the remainder, phosphate of lime. It is a brownish black, the brown color being partly, at least, due to organic compounds formed during the roasting, which were too stable to be driven off at the temperature. These may be, to a considerable degree, dissolved out by a solution of caustic soda, and the better grades are so treated. These are of a very rich and velvety color.

Lampblack.—Lampblack is made by burning oil with an insufficient supply of air, or rather by thrusting into the flame a large piece of cold porcelain or something of the sort, which so cools down the flame as to prevent perfect combustion, and the carbon is deposited on the cold surface. Similar blacks are made from gas-flames, but the details of these processes are not generally known, and the variety of products is surprisingly large. Lampblack is always a bulky substance; of some of the finer sorts only 4 or 5 pounds can be packed into a barrel, while of some of the coarser kinds 20 or 30 pounds may occupy the same space. It is sometimes adulterated with bone-black, but this makes it much heavier. The texture of lampblack is inconceivably fine; mixed with oil in any considerable quantity it greatly retards its drying, which may be due partly to its obstructing mechanically the penetration of oxygen, and is certainly partly due to the action of oily matters always found in it. It is no doubt due to these that we find a surface which has been painted with lampblack retards the drying of any paint applied over it. Bone-black is also a non-drier, but in a less marked degree. A very small proportion of lampblack is used to affect the color of other paints; liberally mixed with driers it is used alone, especially for signs and the like; it is mixed with red lead to retard the setting of the latter and to get rid of its glaring color.

Lampblack, in the natural dry state, contains a large amount of air, apparently condensed on the surface of its particles. Analysis of a given weight of lampblack shows often 20 per cent. of its weight to be oxygen and nitrogen, in apparently atmospheric proportions; a pound of lampblack, measuring perhaps one-fifth of a cubic foot, contains 2½ cu. ft. of air; and the actual volume of the lampblack in this pound is not one-fifth, but less than one one-hundredth of a cubic foot; it appears to occupy twenty times as much space as it would if it could be compressed into a solid mass. It is said that no one has ever made what would strictly be regarded as a satisfactory chemical analysis of this substance.

Graphite is a mineral, a crystallized form of carbon, not used in common paints, but only as a preservative against rust on iron. Its use for that purpose will be discussed later.

Grinding.—All these pigments may be made into paints by grinding them with linseed-oil. There are two ways of doing this: in one case we mix the pigment to a paste with oil in a mill especially designed for the purpose, and this "paste color," as it is called, is thinned with more oil, with more or less driers and turpentine; in the other, we put the oil and dry pigment into a "mixer," usually a vertical cylindrical vessel whose height is less than its diameter and which is provided with some sort of stirring apparatus, the simplest being a vertical revolving shaft with blades extending radially; after being thoroughly mixed the oil and pigment are run through a burr-stone mill to make a homogeneous mixture. Sometimes it is necessary to put it through the mill a second time or even a third, when it is put into suitable packages for shipment. It is not unusual to have some turpentine in the mixture; one effect is to hurry the drying, because there is less oil to dry, and because the turpentine itself acts to some extent as a carrier of oxygen; another result is that the film contains a larger proportion of solid pigment than it would otherwise have.

Value of the Pigment.—The effect of a pigment, aside from its color and any chemical action it may exert, is threefold. Oil dries to a more or less porous film; and even a film of varnish is not entirely without porosity. The particles of pigment stop up some of these pores; this makes the coating more impervious and consequently better. An oil-film when dry is a tough but rather soft substance, easily scratched off; but the pigment is a hard substance and imparts hardness and capacity for resisting abrasion to the film. It is obvious that if we mix a solid powder with oil, the mixture will be of a much thicker consistency than oil alone, just as mud is thicker than water; hence we can spread a much thicker film of such a mixture over a surface than we can of oil alone, and this results in having a thicker film, which in itself is desirable. So the film of paint is less porous, harder, and thicker than an oil-film. If the oil used be boiled oil, the paint may be nothing but pigment and oil; though, as has been said, turpentine is sometimes a good addition. But if it be raw oil, such a mixture will require a week before it seems to begin to dry, and this prevents the use of raw-oil paints for most purposes, unless we add to the mixture an amount of drier sufficient to make it dry to the touch in a day or thereabouts. It is a very common practice to add to the oil more or less oleo-resinous varnish, the object being to make a glossy paint and one somewhat harder. It is much to be regretted that it has become common to use for this purpose a cheap rosin varnish, which is an injury to a good oil paint in every way. Such a paint does not dry properly, and the film will soften and blister if exposed to heat; if very much varnish is used it will make the film crack; it is the cause of most of the cracked paint we see. But if a good varnish made of hard resins is used, the effect will be exactly the opposite. The trouble is that any varnish which ought to be used materially increases the cost of the paint, and the maker, who finds it difficult enough to get a price which will enable him to use pure oil, uses a varnish which costs less than the oil. Such a varnish must be pale in color, or it will affect the color of the paint, and can be made only of common rosin.

The adulterants of oil are legion. The cheapest are made of mineral oil; these are of little or no value. It should be said that, as compared with pure linseed-oil, nothing which can be added to it increases its value except a good varnish; but some of these things have some power to form a film and in that sense may be said to have value. Probably the best is fish-oil, which easily combines with driers, and if mixed in not too great proportion with linseed-oil forms a film which dries after a fashion, though slowly, and has fairly good weather-resisting qualities. A mixture containing twenty per cent. of boiled fish-oil is believed by some good paint-manufacturers to be superior to linseed-oil alone for a roof-paint, but this is doubtful.

Soya-bean oil is considerably used in certain paints; it is a non-drying oil, but when mixed with tung-oil or a mixture of that and linseed-oil it forms a film, especially if used with driers. For this purpose the best pale soya-oil is selected; it is heated eight or ten hours at 500° F., which bleaches it nearly colorless, and it will then respond somewhat to driers.

COACH-COLORS.

For painting carriages and coaches oil paints are too soft and cannot be made to take a sufficiently smooth surface. It is necessary to have a paint which will be hard and which can be rubbed down with pumice-stone until all irregularities of the surface disappear, and an oil paint will never get hard enough for this.

The pigment is, therefore, ground in a special hard-drying medium, called grinding-japan, such as has already been described. This contains oil and resin enough to make it an effective binder, and so much lead and manganese in solution that it will not only dry hard itself in an extremely short time, but so effective is it as a drier that paints ground to a paste in this vehicle, and thinned just before use with a suitable mixture of oil and turpentine, will dry in a few hours to a perfectly hard surface, ready for the next operation.

Grinding-japan.—Some of the cheaper sorts of grinding-japan are made with a considerable proportion of common rosin, and some have been made with some of the varnish resins, but the best of them have the best quality of shellac for the resinous ingredient, as has been stated in a previous chapter, and the real secret is in the purchase of the best materials and the use of a sufficient quantity of good shellac. This, of course, makes the cost increase, but it is in the end economical, because coach-colors are sold by the pound instead of the gallon, and for rather high prices, as they must be because of the labor expended on them, and on account of the chemical activity or potency of the vehicle in which they are ground they are more liable than most paints to undergo spontaneous changes inside the can before being opened; losses of this sort, which fall on the manufacturer, are much less if the japan is of the best quality. The best is actually and literally the cheapest. The carriage-painter requires paints of excellent quality and expects to pay good prices for them, consequently pigments are used which are altogether too expensive for oil paints; no pigments used by artists are too expensive for the best of this work.

Water-cooled Mills.—These paints cannot be ground in an ordinary mill, because the friction develops heat and heat starts up the chemical activity of the japan, with the result that the color and consistency of the product change; so they are ground in a water-cooled mill. In such a mill the stones are cemented into iron shells, just large enough in diameter to receive the stone, which, however, does not fill the cavity to the bottom; its edge is cemented to the interior of the iron shell, and a flat space remains back of the stone between it and the iron. Through this space a stream of cold water constantly flows, and thus the stone is always prevented from heating. Both upper and lower stones are thus water-cooled and the proper operation of these mills calls for the superintendence of a specially trained foreman, who receives high wages, and is commonly ranked next to the superintendent of the works. The colors as they come from the mill should be constantly watched and tested against standard samples, not only for fineness, but especially for color. The operator has a slip of plain glass, on which with a palette-knife he smears a bit of paint; in contact with it he then lays on a bit of the standard; turning the glass over and looking at the paint through the glass, the slightest difference is immediately noticeable. For the benefit of those not familiar with these operations, it may be said that the ordinary burr-stone mill, such as is used for grinding all sorts of substances—for such mills are used on most diverse materials and will economically grind a larger number of substances than all other kinds of pulverizing machines combined—consists of two flat circular stones, the upper of which is fixed in a rigid frame, and has an opening in the centre, called the eye of the stone, into which is dropped the material to be ground; the lower stone, which has no eye, is supported somewhat loosely on the upper end of a shaft, in such a way that when the shaft is made to revolve the stone revolves, but it is loose enough so that when pressed against the lower side of the upper stone it may adjust itself to that, although the plane of their junction may not be at right angles to the axis of rotation; in which case the lower stone will wobble as it revolves. The fineness of grinding is determined in part by the closeness with which the stones are pressed together. In the best form of water-cooled mill this construction is considerably modified. The lower stone, in its metal shell, is screwed firmly on the top at the shaft, like a face-plate on a lathe, so that it cannot vary its position; the upper stone, instead of being fixed to a rigid frame, is held in a frame provided with a universal motion, essentially like the gimbals which support a ship's compass, and this whole frame may be drawn down by a tension screw, so as to make the upper stone fit itself to the position of the lower one. A little consideration will show that in the common form of mill, having a loose lower stone, when the stone is in rapid motion it will tend, by centrifugal force, to take a position at right angles to the axis of rotation, and as this is not permitted by the rigidity of the other stone, it will press against the latter on one side and be free from it on the other; which is a fault, because the two stones should be pressed together in all parts equally. This defect is obviated in the newer form of mill, because the lower stone revolves on a rigid bearing, and though it may not be dressed truly in a horizontal plane, the centrifugal force can produce no effect on its position; the upper stone, which is pressed against it, has no rotary motion and is, by the universal joint in which it swings, pressed uniformly all the time. It was for a long time believed, and by many experienced but not well-informed people is still believed, that colors can be ground to an extreme degree of fineness only on a stone slab with a muller, as described by Cennini, in a passage already quoted, because with such a rudimentary apparatus the intelligence and watchful patience of the operator secures a uniform grinding and the slowness of the operation prevents heating; at least, it is the operator and not the paint that gets warm; but in a water-cooled mill of the improved design, which has been described, these good results are automatically secured and the paint is besides protected from the action of the air and the dust during grinding, and by putting it through the mill as many times as may be desired it may be ground to any degree of fineness. Artist's colors of unequalled excellence are now made in this way, and it is obvious that colors can be ground in a volatile medium like turpentine or varnish only with such a machine. These mills have been in use about twenty years, but are still unknown to many. Water-cooled mills of the older pattern are of much earlier date.

Few of my readers know where to look for the oldest paint-mill in America. It was very different from those now in use; it consisted of a large flat rectangular stone, hollowed out to form a stone trough capable of holding seventy-five or a hundred gallons of paint; the materials for which, having been put in the trough, were mixed and ground together by a stone ball, about two feet

in diameter, which was rolled from end to end of this receptacle, and served both to mix and grind the contents.

This mill is in Boston Mass. As you walk down Hanover Street from Washington Street, keeping on the south side of Hanover, just before reaching Blackstone Street, you may notice a narrow lane called Marshall Street, turning off to the right. Down this alley about fifty feet there is a little open triangular space; when you reach it turn around, and in the foundation of the building in front of you (which faces on Hanover) you will see the "Boston Stone," as represented in the accompanying illustration. This is the old paint-mill which was imported from England about the year 1700 by a painter who had a little shop in the old wooden house that then occupied this site. It is, therefore, more than two hundred years old.

Following the custom of the times, he placed on the Hanover Street front of his home the English coat of arms carved in wood, with his initials and the date, 1701, upon it, from which his dwelling came to be known as the "Painter's Arms." When the old frame house was removed in 1835, the "Painter's Arms" were taken down and replaced on the new building.

At the same time, the Boston Stone, which had also been temporarily removed, was put back in the position it now occupies. The round stone above, which is about two feet in diameter, was the grinder or "muller," and was rolled back and forth in the trough hollowed out in one side of the larger stone underneath and thus ground the paint. The grinder was once lost for a time, and was discovered in digging the foundation for the present building; the trough-stone was found in the yard of the house when the place was bought from the painter, and as the stone was of no use there, it was removed to the corner of the house to protect the building from injury by carts. For some time after it had been placed in this position it was utilized by surveyors as a starting-point from which to run their lines. The original stone, the capacity of which is said to have been nearly two barrelfuls of paint, was finally split into four pieces, and it is one of these fragments that now rests under the grinder with the inscription "Boston Stone 1737" cut in it. The way in which it came to be called the Boston Stone is thus described by a local antiquarian:

"When I was a boy," said Dr. Elliott, "in passing the building, I saw a lad named Joe Whiting, whose father occupied the shop, writing on the stone these words: 'Boston Stone, Marshall Lane.' After I became a man, I asked Mr. Whiting who set the boy at work on the stone. He said: 'Marshall Lane at that time not being named, it was difficult to designate his place of business. A Scotchman who opened a shop for the sale of ale and cheese, directly opposite, made a complaint of the difficulty. He said in London there was a large stone at a certain corner marked London Stone, which served as a direction to all places near it, and if I would let Joe write the words Boston Stone on this, people would notice it and it would set them guessing what it meant, and would become a good landmark.'"

That the Scotchman was right in his belief is proved by the fact that for generations past the dull red, weather-stained stone, with the deeply cut, white lettering, has been one of the landmarks of the North End, so well known that we find it in Whittier's stirring appeal:

"Woe to thee, when men shall search
Vainly for the Old South Church;
When, from Neck to Boston Stone,
All thy pride of place is gone;
When from Bay and railroad car,
Stretched before them wide and far,
Men shall only see a great
Wilderness of brick and slate!"

CHAPTER XV.

VARNISH OR ENAMEL PAINTS.

ALL oleo-resinous varnishes are more or less dark in color The very pale ones are yellow; the medium ones are brownish yellow; the dark ones are yellowish brown. If, therefore, we apply a coat of varnish over a painted surface, the color of the latter will be changed; and in order to avoid this, the painter may mix some of his pigment in the varnish, thus bringing the pigment to the surface and displaying its color, with less, but not entirely without, influence from the color of the varnish. Of course, if the paint is dark in color, the color of the varnish is of no account, but to make a white enamel paint taxes the resources of the most skilful varnish-maker. There are indeed varnishes which are nearly free from color, such as bleached shellac; but shellac is an acid resin, and if we mix white lead or white zinc with it, a chemical action is at once set up and a doughy mass not in the least resembling paint is formed. There are some spirit varnishes which may be mixed immediately before using with these pigments, but they lack durability.

Damar Enamel.—The one most generally liked on account of its free working quality, its color, and its moderate price is damar, but this has not a very good lustre; it is, and always remains, soft, or at least does not approach an oleo-resinous varnish in hardness, and it soon loses whatever gloss it had in the beginning, and if exposed to the weather it is almost immediately destroyed. It is a good deal used in making white enamel for iron beds and the like, and is hardened by baking. This also greatly improves its lustre and its durability, and, as it is not to be exposed to the weather or even to the sun, it is fairly satisfactory for this purpose. White is the color of sunlight, and a surface of clean snow is probably the whitest thing we ever see; no pigment will bear comparison with it. So when we talk of paints white is a comparative term; some paints look more like white than others, and the best of them when ground in oil look decidedly yellow, from the color of the vehicle, if compared with the pigment either dry or made into a water-color. Artists frequently use poppy-oil or walnut-oil, which are drying oils (but less drying than linseed) because of their pale color, but the advantage is only temporary, because they yellow with age quite as much as linseed. Indeed they are much worse because it is necessary, in order to make them dry, to load them with driers far beyond the need with linseed-oil, and this, as has been explained, has a most injurious effect on their permanence. All these oils with age turn yellow, especially in the dark or in weak light, and may from time to time be bleached by exposure to the direct sunlight. A painted surface, as, for example, the outside of a house, continually exposed to the sun remains white. Varnish paints, however, do not change in any such marked manner; they do not grow yellow, nor are they bleached by sunlight very much. White lead or zinc ground in oil is whiter than any oleo-resinous varnish paint, at least after being sun-bleached, but very white enamel paint may be made if the necessary expense is warranted.

These enamel paints are certainly the highest achievement of the paint-maker's art. They are, like the varnishes, unlimited in variety, and may be made of quality suitable for the most diverse uses. If they are to be used on furniture, they will be made with a hard varnish and may be rubbed and polished like a varnished surface; if for interior woodwork of a house, a more elastic varnish will be used, and to stand exposure to the weather the varnish must be made especially for such service. The maker must know first what pigments he will have to supply, then he will consider what varnishes he has found suitable for use with these pigments; from a list of these he selects such as will make a vehicle at once elastic in a high degree and hard to resist abrasion, with toughness to act as a binder and, especially if it is to be used on metal or any impermeable material, extremely adhesive. When a suitable mixture is found and ground with pigments which are chemically inert and permanent we have a paint of the highest degree of excellence. As a matter of practice the greater proportion of enamel paints are light in color and, therefore, have white lead or white zinc as a base, and the varnish used must be such as will work properly with these pigments, which, as they cannot be called chemically inert, are somewhat difficult to fit with an otherwise suitable vehicle. The kauri varnishes seem to work better than any others, perhaps because they are so completely free from acidity; those made from the softer resins and from some of the harder resins do not behave as well.

Defects of Enamels.—The trouble is that the mixture becomes thick, and if we thin it with more varnish or turpentine we, of course, have less than the normal amount of pigment in it and it lacks covering power; moreover, the paint becomes ropy with age and no amount of thinning will make it spread freely and uniformly. I have never seen enamel paint containing much white lead (and zinc, which works better in cheap enamels, is quite as bad in those of better quality) which did not deteriorate somewhat on standing a long time. This is a serious obstacle to their general use, and even when fresh they do not and can not flow like an oil paint, nor do they equal the oil paints in covering power. This is because the varnish is much more viscid than oil alone, and if we put as much pigment to a gallon of varnish as we would do to a gallon of oil, the mixture would be too thick to work properly under the brush. The enamel paint is, therefore, comparatively transparent and it requires a great many coats to make a substantial foundation of color. Hence it is the common practice to lay on a foundation of oil paint, which has much more covering body, until we get the desired color; then finish with as many coats of enamels as may be necessary. This is a violation of the general rule, to be hereafter discussed, that the under-coat should always be harder or not less hard than the outer one, and for severe exposure out of doors it should not be followed; but for interior work, where nearly all enamel is used, it is usually satisfactory, and it is not only less expensive but far less tedious than building up a body of solid enamel paint.

Enamel may be Thinned with Varnish.—When it is necessary, as it sometimes is, to thin the enamel paint at the time of applying it, this should never be done with oil, and it is not advisable to do it with turpentine, but with varnish; and the varnish should be slower-drying than the enamel. It would, of course, be right to use the same varnish the enamel was made of, but this is not often possible, and it is good safe advice to use for the purpose a finishing carriage-varnish, or "wearing body" varnish as it is often called, which is at once pale in color, elastic, and possessed of the very finest working qualities. Spar-varnish is also suitable. These varnishes should, of course, be from reliable makers, because not a little inferior varnish is put out under these names. It is extremely dangerous (that is, to the quality of the paint) to add oil to any enamel paint, or to a varnish, for that matter; there is no objection, usually, to adding a good varnish to oil or an oil paint, for if it does no good it probably will do no harm; but adding oil to varnish is only less reprehensible than adding drier or japan to it, all of which things are not infrequently done by persons of a sufficient degree of depravity. Enamels are sometimes made by grinding the pigment in oil to a paste and then thinning this with varnish, and fairly good enamels may be made in this way; but it is better to grind the pigment directly with the varnish, because adding in even this indirect way oil to the varnish slows down its drying beyond all reason and makes it necessary to use a quick-drying varnish, when we might just as well use all varnish and use one which would be slower and much more durable and have better working qualities. On the other hand, remembering what has been said about the necessity of using mixtures of different varnishes to get a compound of the right character, we may usually select a varnish to grind the color into a paste, which will be especially suited for grinding, and in which the pigment will keep well, and when the paint is called for, some of this paste may be taken and mixed with the varnish which is to be used, the mixture run through a mill to insure the proper mixing, and it is ready to ship. It is generally a good plan to have your principal varnishes mixed and tanked for a month or more before putting into cans, because it takes a long time for the components which have sensibly the same physical qualities to become uniformly mixed, and this is an objection to thinning a varnish, even with pure turpentine, and a reason why such a practice seems so seriously to injure its working qualities; if we add the turpentine and mix it as well as we can and then set it away for a month or two, we shall find a great difference. Any one may illustrate this by making a syrup of sugar and water, and pour some of this thick, ropy syrup into a bottle of pure water; though perfectly miscible, it will take an astonishing amount of shaking before the two liquids become, even to the eye, completely mixed. But this does not hold true in case of these enamel paints, because we run the mixture (which we admit to be an imperfect one) of paste color and varnish through the mill, and this mixes them in the most perfect manner; the mixture is much more complete than would be the case if no pigment were present.

It has already been said that some of these paints are made with damar; it has also, in an earlier chapter, been remarked that damar varnish is often adulterated with rosin, even up to the vanishing-point, and these various statements may be combined, when they explain the composition of some of the most atrocious compounds known in the whole paint business. It would be a waste of words, and of the sort of words which do not look well in a book, to describe these products, which are in no small degree responsible for the poor opinion of enamel paints held by many worthy and otherwise intelligent people. It is not to be denied that varnish or enamel paints have their drawbacks; as has been said, they do not work as freely as oil paints, they are, especially in white, a little less brilliant in color, they do not cover as well, and they do not keep well in the can, but they work freely enough so that a good workman can do the finest sort of work with them when they are fresh; their lustre more than makes up for any slight yellowing of the color, which is at any rate noticeable in hardly anything but white; they have fair covering quality, and the dark shades, which are made with opaque pigments, cover perfectly; some of them appear to keep in the can indefinitely, and even the whites, which are the worst, will usually keep, especially in a cool place, a year or more, which is longer than any paint ever should be kept, for it is a general rule that paint is best when it comes from the mill. Varnishes are thought to improve by keeping, but such a thing has never been supposed of paint, even oil paint, except that white lead and oil are supposed to improve for a time.

Special Enamels for Special Uses.—Paints of this sort, like varnishes, should be made for the special uses to which they are to be put; it is not practicable to use one kind for all sorts of work, interior and exterior, and even out of doors there are many places where a fine appearance is essential and others where this is of less account than extreme durability. Dark and dull colors are in general more durable than light and brilliant ones; this is true also of oil paints. If a paint is to be subject to frequent rubbing, as on a hand-rail, or to blasts of dust, as on a railway car, it must have hardness to resist abrasion, or it will not answer at all; and it may be that the necessary hardness cannot be had without making the paint so inelastic that it will in time crack from the rapid and extreme changes of temperature it must endure; but if it is to stand the weather alone, it may be made so tough that it can never possibly crack, and, being practically water-proof, which an oil paint is not, it will resist decomposition longer than any other preservative coating. But such a paint as that would be entirely out of place on the interior finish of a house, and if applied to articles of furniture, it would make a horrible mess. Yet with suitable enamels the most dainty articles of the toilet-table are painted, and all the most valuable pictures, made in the middle ages by the great masters of art, have come down to us painted with pigments ground in just such varnish as we are making to-day.

CHAPTER XVI.

CHINESE AND JAPANESE LACQUERS.

THE Jesuit missionary Father D'Incarville, who was a corresponding member of the French Academy of Sciences, wrote from China a memoir on Chinese varnish; this was, as stated in the text, a few years after the death of the Emperor Yung-ching or Yong-toking, and in the beginning of the reign of Keen-lung; that is, a few years after 1735. This memoir was said by Watin to be practically inaccessible in 1772; inaccurate statements said to be based on it appear in various encyclopædias; and as the writer has been so fortunate as to have secured a copy, the following translation, which is complete with the exception of a few irrelevant sentences, is now presented, as an important addition to our knowledge of the subject. The author claimed no knowledge of varnish in general, but simply wrote out his own observations. The mention of tung-oil is the earliest which has come to the notice of the translator.

D'INCARVILLE'S MEMOIR.

It is commonly known in Europe that Chinese varnish is not a composition, but a gum or resin which runs from a tree which the Chinese call Tsichou, or varnish-tree.

This tree grows in most of the southern provinces of China; it grows wild in the mountains; the trunk of the tree is sometimes a foot or more in diameter. Those which are cultivated on the plains, or on certain mountains, the Chinese tap for their juice when they are as large as one's leg; these cultivated trees do not live more than about ten years.

Varnish-trees.—The varnish-tree is easily propagated from slips; in the autumn they select such branches as they wish to use for this purpose; they pack the twig not too firmly with earth, a few inches beyond the place where it is to be cut off, and this earth is formed into a ball about the size of one's head, and wrapped in tow or linen cloth to keep it in shape; they water it occasionally to keep it moist; the branch puts forth roots, and in the spring it is cut off above the ball of earth and is transplantable.

This tree grows as well in an open country as in the mountains, and the varnish is quite as good, provided that the situation is favorable; if the trees have not a good exposure or are in the shade, they give more varnish, but not as good. This tree requires no other culture than to have the earth stirred beneath it, and to fertilize it with the leaves which fall from the tree.

Collection of Varnish.—The varnish is collected in summer. If it is a cultivated tree, the sap is drawn three times; that which is taken first is best, and the second is better than the third. If the trees are wild, they tap them but once a year; or if they do it three times, they then leave the tree undisturbed for three years.

To obtain the varnish they make, with a knife, three cuts which go through the bark but do not raise it. These three cuts form a triangle; in the base of this triangle they insert a clam-shell to receive the liquid which runs out from the other two cuts; this is the practice with cultivated trees. With wild ones they make a cut in the tree with a hatchet, as they do in Europe to get turpentine from the pine. It is possible to make twenty incisions in one of these large trees; but on the cultivated ones they set not more than four shells at a time, and they make new cuts each time they wish to get more varnish.

It sometimes happens to the great wild trees that after having made the incisions the varnish does not run; it is then necessary to slightly moisten the cut surfaces; for this they provide themselves with hogs' bristles, some of which they moisten, if water is not at hand, with saliva, and put about the place; which treatment, by moistening, opens the pores of the tree and lets the varnish escape.

When it appears that one of the wild trees is exhausted, and there is no hope of getting more from it, they cover the top of the tree with a little straw, which they set on fire, and all the remaining varnish in the tree is precipitated into the numerous incisions which they have made near the foot of the tree.

Those who collect it go out before daybreak. In the morning twilight they set the shells in place; each man can set about a hundred. These they leave about three hours, after which they collect the varnish, beginning with those first set. If the shells are left longer the varnish is better, but less in quantity, because the sun evaporates the aqueous parts, and this would cause a loss to the seller.

The collector carries, hung to his girdle, a little bucket of bamboo in which he deposits the varnish. To do this he moistens his finger by passing it over his tongue, and in wiping out the shell the varnish does not stick to his finger because it is moist. Some use a little wooden spatula which they moisten with water or with the tongue.

Storage of Varnish.—What each one collects in his little bucket he carries to the dealer, who preserves it in casks. These buckets and casks are carefully covered with a sheet of paper, as confectioners cover their jars of preserves with a circular piece of paper cut to fit the top of the jar. Those who collect the varnish do not take the trouble to cut out the paper in this way, but they fit it over the mouth of the vessel, to preserve the varnish better, and to prevent the entrance of the least dust. Their paper, which they call Moteou-tchi, is very suitable for this; it is made of hemp.

Its Poisonous Qualities.—It is necessary to take care, in covering and opening the vessels which contain the varnish, not to expose one's self to the vapor; the face should be turned to one side; unless one is careful there is risk of getting an eruptive disease, such as is caused by the poison-ivy of Canada, except that the poisoning by varnish is much worse; but it is not fatal. To lessen the burning sensation of these blisters they bathe them with cold water, if they have not burst; but if they have, they rub them with the yellow matter taken from the bodies of crabs, or, if that is not to be had, with the flesh of shell-fish, which by its coolness gives much relief. Few of those who work in varnish are exempt from being attacked once by this disease. It is somewhat singular that people who are active and highly colored are more subject to it than those of a phlegmatic temperament. Some of the latter are never attacked.

To keep the varnish they set the vessels in caves where it is cool and not too damp; being well covered, they keep it as long as they wish.

The varnish, when it comes from the tree, resembles liquid pitch; exposed to the air it takes on a reddish color, and soon becomes black, but not a brilliant black because of the water which it contains.

Three Kinds.—The Chinese distinguish three sorts of varnish: the Nien-tsi, the Si-tsi, and the Kouang-tsi. The three words, Nien, Si, and Kouang, are three names of the principal cities from which they get the three kinds of varnish, namely, Nien-tcheou-fou, Si-tcheou-fou, and Kouang-tcheou-fou. Tcheou-fou signifies principal city, or city of the first class.

The Nien-tsi and the Si-tsi are two species of varnish which they employ to make the black varnish; the Nien-tsi is the better, but it is very difficult to get it pure: the dealers mix Si-tsi with it.

The province from which they get the Nien-tsi is not very extensive, and so there is not enough of it for all the work done in China. The Nien-tsi is of a more brilliant black than the Si-tsi; it costs at Pekin about a hundred sous for a livre (one dollar a pound); the Si-tsi is one-third as costly. The Kouang-tsi is of a yellowish color; it is more pure, or contains less water, than the other kinds.

Tong-oil.—It has another advantage: it is, that in using it, they mix it with about half of Tong-yeou, which is another varnish, or rather an oil very common in China, which, at the places where it is produced, costs only two or three cents per pound. I have heard say that they sell it at Paris under the name of Chinese varnish. It resembles turpentine. I have said that they mix half of this oil in the varnish called Kouang-tsi; that depends on the purity of the varnish: if it is very pure they add more than half; then the price is nearly that of Nien-tsi.

Drying by Evaporation.—It is first necessary to remove from it the aqueous part by evaporating it in the sun; unless this is done it will never become brilliant. The Chinese set about it in the following manner: they have for the purpose large flat vessels the rim of which is not more than an inch or an inch and a half in height; these are a sort of basket of woven reeds or osiers, plastered with a composition of earth or ashes, over which is a single layer of common varnish. They are convenient for holding the varnish while it evaporates, and it can be removed from them easily.

If the sun is warm, two or three hours are enough to remove the moisture from the varnish, which is not more than an inch deep in the dish. While it is evaporating they beat it with a wooden stirrer almost incessantly, turning and re-turning it; first it forms white bubbles, which diminish in size little by little; finally they take on a violet color; then the varnish is sufficiently evaporated.

Further Treatment.—When from this varnish, which I suppose to be Nien-tsi, to which they have added a fourth part of Si-tsi, they wish to make the fine ordinary varnish of China, after having evaporated it about half they add to it about three-quarters of an ounce of hog's gall to a pound of varnish: it is necessary that this gall should have been previously evaporated in the sun until it becomes somewhat thick; without this hog's gall the varnish would be lacking in body, it would be too fluid.

After having stirred this gall with the varnish for a quarter of an hour, they add a quarter of an ounce of Roman vitriol (sulphate of copper) to each pound of varnish; this vitriol they have previously dissolved in a sufficient quantity of water (sometimes they use tea); they continue to stir the varnish until, as I have said, the bubbles which form on the surface show a violet color; this varnish, thus prepared, is called, in China, Kouang-tsi, or brilliant varnish; the word Kouang means brilliant.

Black Varnish.—Within a few years the Chinese have imitated the brilliant black varnish of Japan. This the Chinese call Yang-tsi; Yang signifies the sea, as though to say a varnish which comes from over seas, Japan being separated by the sea from China.

The Yang-tsi differs from the Kouang-tsi only in this, that when the Kouang-tsi is entirely evaporated they add to each pound of it an eighth of an ounce of bone-black made from the bones of a deer, reduced to a fine powder. (The Chinese claim that the ribs make better bone-black than the other bones.) We tried ivory-black; the workman found it better than bone-black, and begged me to supply him with it. Besides this bone-black they add an ounce of oil of tea, which they render siccative by making it boil gently, after having thrown into it, in winter, fifty grains of arsenic, half red arsenic or realgar, half gray or white; in summer six grains are enough; they stir this arsenic constantly in the oil with a spatula. To see when the oil has become sufficiently siccative they let a drop fall on a piece of cold iron, and if, when they touch the tip of the finger to this thickened oil, it can be drawn out a little into a thread, it is done. This oil gives a fine brilliance to the varnish.

Tea-oil.—The Chinese say that no other oil than tea-oil will dry the varnish, and that any other oil will separate from it—which I doubt; the Tong-yeou rendered siccative does not separate, and I believe that any other very siccative oil would have the same effect.

This tea-oil is made from the fruit of a particular kind of a tea-tree; it resembles our plum-trees; they cultivate it only for its fruit and not for its leaves. This fruit resembles our chestnut, except that the outer husk does not bristle with points like our chestnut-burs. The fruit of the Tong-chou, from which they make the Tong-yeou, resembles it also.

The Chinese have still three other preparations of varnish, as follows: the Tchao-tsi, the Kin-tsi, and the Hoa-kin-tsi. The Tchao-tsi is that which they throw upon their powdered gold to imitate aventurine. Tchao means to envelop, to cover, as one would say an exterior varnish. This varnish is a transparent yellow; it is composed of half Kouang-tsi, that is to say, that which comes from Kouang-tcheou-fou, and half Tong-yeou rendered siccative. The Kin-tsi has its name from the color of gold; the word Kin means gold. In fact, this varnish is of a golden yellow; it is composed of the most common Si-tsi, or that which has been collected as the third crop, half varnish and half Tong-yeou. It is upon a layer of this varnish that they scatter their gold-powder, over which they spread, as I have said, a coat of Tchao-tsi. The gold-powder thus set between these two coats of varnish imitates aventurine; but it is only after a long time, for it is much more beautiful after a lapse of years than it is within a few months; I have observed it. The Hoa-kin-tsi is that which is used by painters in varnish for tempering their colors, whence comes the name Hoa, which means to paint; that of Kin, because it serves for painting in gold or for designs in gold: the varnish is composed of half Tchao-tsi and half Kin-tsi.

PREPARATION OF VARNISH.

Straining.—The first thing to be done is to strain the varnish so as to purify it as much as possible from dust and sediment. For this purpose they prepare some cotton as if to make a counterpane; they spread three layers of cotton thus prepared on a piece of thin cloth; on these layers of cotton they turn the varnish, either Yang-tsi or Kouang-tsi evaporated, and they cover it very accurately with the cotton, layer by layer, cutting off, if it is necessary, in the folds, a little of the cotton, so that it shall lie more smoothly and evenly. When the three layers of cotton have thus been spread upon the varnish, one after another, they cover the whole with the cloth, to press out the varnish which is thus wrapped up. The machine which the Chinese use for this operation is very simple, and appears to me convenient. When the varnish does not trickle out any more they open the cloth and with their fingers pull to pieces the three layers of cotton, so as to be able to press out as much as possible; they repeat this manipulation two or three times, until they can get no more varnish out; finally they throw away the cotton and recommence the operation with three other layers of new cotton. They strain the varnish a third time; the third and last time they do not use cotton, but a layer of Sée-mien. The Sée-mien is made of the outer parchment which covers the chrysalis of the silkworm. They spread upon the thin cloth, in place of cotton, seven or eight layers of Sée-mien; they envelop the varnish as they did before when they used cotton, and press it out. The varnish thus filtered is reckoned very pure. For this operation it is necessary to have a place that is perfectly clean, where there is no fear of dust, so that at the end there shall not a grain of dust fall into the varnish thus purified. The Chinese receive it as it runs out from the filter in a perfectly clean porcelain vessel, covering the vessel with a sheet of the paper called Maoteou-tchi, which I have already mentioned, and put it in a suitable place until they wish to use it, when they do not wholly uncover the vessel, but only raise one corner of the paper cover.

APPLICATION OF THE VARNISH.

The Workshop.—The workshop ought to be an extremely clean place, situated where it will be as much as possible out of the way of dust; to secure this result they cover the wall with mats, and over these mats they paste paper carefully everywhere, so that one cannot discover the least little exposure of the matting; the very door of the workshop, which is made to close tightly, is covered with matting and papered like the rest.

Dust is Avoided.—When the workmen have to apply the varnish, especially the finishing coat, if the weather is such that there is no fear of their taking cold, they wear only a pair of drawers, not even a shirt, for fear of bringing dust into the workshop; if the season does not permit them to dispense with their clothing, they take great care to shake off the dust before entering, and they wear only such clothes as the dust will not easily adhere to; they are particular to avoid any disturbance in the workshop, and no unnecessary persons are allowed to enter.

The first thing the workmen do is to clean the brushes which they are going to use. They have a little bowl with a little oil in it, in which they clean them, for fear that there may be some particles of dust in the brushes; they test them carefully before they take them finally from the oil. The brushes being perfectly clean, they uncover a corner of the bowl which contains the varnish which has been thrice filtered, as has been described. In taking the varnish on the brush they only touch it to the top of the varnish, and in withdrawing the hand they turn the brush two or three times to break off the thread of varnish which strings from the brush.

In spreading the varnish it is necessary to pass the brush in every direction, applying it equally everywhere; in finishing the brush must be always drawn in one direction.

Each Coat Dried and Rubbed.—Each coat of varnish has no greater thickness than that of the thinnest paper; if the varnish is too thick it will make wrinkles in drying; it is troublesome to get rid of these; sometimes one is even obliged to cut them off with a chisel, instead of the easier method of grinding them off with cakes made of brick-dust, such as will be described later. Although it may not actually form wrinkles, such a coat of varnish will be very troublesome to dry. Before the application of a second coat of varnish it is necessary that the first coat be well dried, and should have been polished with the cakes made of brick-dust.

Moist Air Dries Varnish.—In order to set away the varnished pieces to dry as soon as they are varnished, they are accustomed to have shelves all around the workshop from top to bottom; on these they place the varnished articles, setting them lower or higher according as they wish them to dry more or less quickly. The humidity of the earth dries them more or less rapidly according as they are set nearer or farther from it. When they are absolutely dry they may be put on the top shelves, and left there, if it is thought best. At Pekin, where the air is extremely dry, it is necessary, to dry the varnish, to put it in a humid place, surrounded by matting which they sprinkle with fresh water; otherwise the varnish will not dry. If it is an article which is so situated that it cannot be removed, they are obliged to hang wet cloths about it.

When the first coat of varnish is quite dry it is necessary to polish it; if it is not entirely dry, it will roll up in places when they try to rub it. The day after they have put a piece to dry on the bottom shelf they examine it to see if it is dry; to do this they touch it gently with the tip of the finger; when the finger is withdrawn, if the varnish is felt to be tacky it is not dry enough to polish. There is no risk in leaving a piece several days; the drier the varnish is the better it will polish. It is only necessary to be careful, in damp weather, that the varnish should not be too moist; for then it tarnishes and can never be brought back; if it is a finishing coat, it is lost: it is necessary to rub it and add another coat. To avoid this inconvenience, they do not at such times put pieces to dry on the lowest shelves, but on the second or third; it is better that the varnish should dry slowly. However they polish the foundation to which they are going to apply the varnish, they always find some little inequalities, which one or two coats of varnish will not be able to efface; this is why they are obliged to rub each coat; the varnish which is too thin is liable to be too easily removed. Whatever care they take, some grains of dust are always found in the varnish, which come from the little inequalities removed in rubbing; whence it follows that if each coat were not rubbed, the last coat would be imperfect.

Polishing-powder.—To rub the varnish they form little cakes composed of brick-dust passed through a fine sieve and washed in three waters; after stirring it in water until it is turbid they pour it off into another vessel and throw out that which has settled to the bottom, as too coarse. They repeat this operation three times, and then leave the water to settle; when it is well settled they carefully pour off the water and cover the vessel which contains the sediment, and set it in the sun to dry. When dried they pass it through a fine sieve, they mix it with Tong-yeou, or they drop in some Tou-tse and a little more than half of swine's blood prepared with lime-water. To form it into cakes they roll this material in cloth, give it the form they wish, and finally put it to dry in the shade upon a plank covered with paper; if they put it in the sun to dry, they shelter it, for fear that some coarse particles of dust may fall on it which, in polishing the varnish, would make scratches.

The preparation of the swine's blood with lime-water is made in this manner: They take a handful of straw, beaten and coarsely chopped in pieces three or four inches long; with this straw they treat the blood in the way pork-butchers do to separate the clots of blood; after which they pass it through a cloth, and a little later they add to it a third of its volume of lime-water which is white with lime, not having been allowed to settle. This milk of lime must be prepared on the spot and immediately added to the blood, which being thus prepared is preserved in a covered earthen vessel.

Rubbing.—To rub the varnish they wet with water the end of the cake of brick-dust, and they rub it vigorously all over the surface to remove the little inequalities caused by any grains of dust which may have been in the varnish or in the brushes; and from time to time they pass over the surface a brush made of long hair, wet with water, holding the varnished article over the vessel in which they wet the brush, to wash off and remove the mud made from the brick-dust, so as to see if there are still any little defects; and they rub them away before they apply a second coat of varnish. They rub the second coat like the first, when it is thoroughly dry; at last they apply the third coat; it is above all things important with this last coat to take all possible care to avoid the least dust.

It is only within a few years, under the reigning emperor, that the secret of the Yang-tsi, or the varnish which imitates the brilliance of that of Japan, has been known outside of the palace. About thirty years ago a private citizen of Sout-cheou, one of the cities where they make the very finest varnished pieces in China, found out the secret, or rather learned it from some Japanese, the merchants of Sout-cheou having trade with those of Japan. It is to be wished that they had also learned the secret of preparing their Tchao-tsi, which surpasses infinitely that of China.

The Emperor Yong-Toking, father of the emperor now reigning, wished to keep it a secret, and did not wish that it should go out of the palace; in fact, the secret remained unknown to the people outside for many years. At last Kien-long, now reigning, was not so careful about varnish as his father, and did not prevent the secret from being known outside the palace. I know one of the workmen who worked in the palace, who has done in my presence the things I have written in this memoir; it is from this same workman, who has worked for three months in our house, that I know what I have written about varnish. He is a Christian and my convert; I have reason to believe that he does not deceive me.

Polishing.—Formerly the Chinese made only the varnish which they call Toui-kouang; Kouang means brilliance, and Toui to remove, as they say of varnish which has lost its lustre; the reason being that they rubbed the last coat of varnish the same as the others, and in that way got rid of its gloss. To partly restore this, after having carefully rubbed this third coat they gave it second rubbing with a bunch of hair which had been wet in water in which they had suspended some very fine powder; after this they rubbed it with a piece of very soft silk cloth, and with this in the hand they rubbed vigorously, until the varnish became bright. In the places which they could not reach with the hand, they attached to the end of a bit of wood a piece of this soft silk, and with this rubbed it; and finally they rubbed the varnished surface with a bit of silk slightly moistened with some clear oil, no matter what kind; this gave the varnish a little gloss, but not to be compared with that of the varnish called Yang-tsi.

The Yang-tsi, on account of the oil of tea which is combined with it and which gives it its brilliance, cannot be rubbed; it is therefore still more necessary to avoid dust than when using Toui-kouang. The only remedy is to hide the defects, in painting the varnished articles, by making the design conceal these imperfections.

In varnishing with Yang-tsi they employ this beautiful varnish only for the finishing coat. The Kouang-tsi, of which they make the Toui-kouang, is perfectly good for the two under coats, because these have to be rubbed. The last coat of varnish ought especially to remain a long time on the shelves at the top of the workshop, for at least fifteen days, before any painting is done on it; there is a chance that the varnish will be sticky; the gold will stick to the places which are not entirely dry.

Observe that when one would make the beautiful varnished boxes, like those of the Japanese, it will not do to have them liable to open at the joints; it is necessary to cover all the joints with strips of the paper called Che-tan-tchi. The Japanese use it, as well as the Chinese, to make their work more substantial; but in China, where they do not care so much for the excessive lightness of these boxes, they use a sort of canvas made of silk, called Kieun, in place of Che-tan-tchi; then their boxes will never come to pieces.

Preparation of the Surface.—To prevent the varnish of the first coat from sinking into the wood they brush the piece over first with gum-water mixed with chalk. The Che-tan-tchi or the Kieun are applied with pure varnish not evaporated. Before putting on the first coat it is necessary, with a piece of stone less harsh than sandstone, to rub well the Che-tan-tchi or the Kieun; to make their surface more uniform, after they have been rubbed, they are obliged to lay on a light coat of the composition of brick-dust which I have already described, immediately before the application of the varnish, which they mix with a half of Tout-tsi. (Note. Tou signifies earth, tsi signifies grain; as though to say, grains of earth; or rather, earth which is in granular form; they find it in abundance in the mountains.)

It is necessary that the Tout-tsi should be passed through a sieve; the whole is mixed with varnish not evaporated, when the composition is very clear and well finished. The Japanese sometimes employ only the Che-tan-tchi, and content themselves with rubbing the pieces, before applying the first coat of varnish, with wax, to prevent the varnish from penetrating the wood. The Chinese sometimes do the same thing; but articles finished in this way are not substantial, and are liable to crack at the joints, especially at Pekin, where the air is extremely trying to wood, no matter how old it may be.

The wood which the Chinese use for making these varnished articles is as light as that used by the Japanese, and if the work of the Chinese is heavier than that made in Japan, it is because the Chinese usually send their best work to Pekin, and wish them to be substantial, fearing that they will not stand the climate of Pekin, where, in spite of all precautions, they will not last unless they are built as solidly as those which are made in Pekin itself.

The wood which the Chinese employ is called Ngou-tou-mou. Mou is the generic name for wood; Ngou-tou is the name of the trees. Its wood is very pliant and extremely light, excellent for musical instruments; they claim that it will give out a better sound than any other wood.

The brushes for applying the varnish are made of hair; those which are used to wash the pieces are made of the beards of she-goats, or they can use that from cows' tails. The paste with which they bind together the hair of the brushes is made of Tong-yeou, litharge, and Tou-tse, which makes a compound that dries very quickly. To this mixture they add a half of the swine's blood treated with lime-water. Another composition may be used for the same purpose, provided that it is elastic and, in working, does not crumble and come out in dust, as sometimes happens to our brushes in Europe.

If, in using varnish, it sticks to the hands, they rub them with a little oil; it is easily removed.

It sometimes happens in time of rain or of high winds that the varnish does not dry; if it does not dry in the usual time, it never will dry. Then the only remedy is to rub it with lime and set it on the lower shelves of the workshop; it will dry in a short time. Before putting it away to dry, it is necessary to thoroughly wipe off the lime with a piece of silk. If the lime has not entirely removed the varnish which did not dry, it will raise up a quantity of little points; these must be made to disappear in polishing the article, after which another coat of varnish is to be applied.

If, in the winter, they wish to evaporate the varnish, as there is little heat from the sun, and the operation would require a long time, they proceed thus: They roll up a mat into the form of a muff, of the size of the vessel in which they wish to evaporate the varnish. They set the mat upright, and place at the bottom a chafing-dish with a little fire in it, and a foot or a foot and a half above it they support, by means of a tripod, the dish of varnish; in an hour or an hour and a half the varnish is evaporated, all the watery part is gone.

In rendering the Tong-yeou siccative, after having drawn it from the fire, when they judge this oil to be sufficiently siccative, while it is yet warm, coming from over the fire, they decant it many times to disperse the fumes which come from it; without this precaution the Chinese tell us that it will give a bad color to varnish.

PAINTING ON VARNISH.

Painting on varnish is suitable only for furniture like tables, chairs, cabinets, and the like; for large articles which one does not look at too closely it produces a good effect; but for small articles which require delicate designs it is not well adapted; it should therefore be confined to furniture and on the inside of boxes, especially large ones.

Only designs in gold are fit for delicate work. However finely finished may be the gold-work on varnish done in China, it is not comparable with the beautiful work which is made in Japan. Up to the present time the Chinese have not found the secret of the water-white varnish which the Japanese apply over their gold designs. The transparent varnish of China, which they call Tchao-tsi, inclines to a yellow color, but a muddy yellow, so that it cannot be used for fine and delicate designs; it may be used to imitate aventurine, as I have already remarked; but this aventurine does not compare with that of Japan. I am not without hope that eventually we may invent in France some varnish which can be applied over the Chinese varnish; and then we will be able to compete with and even surpass the Japanese, our European designs being much finer than those of Japan.

Designs are Transferred.—The following are the details of painting on varnish, as it is done in China. In the first place, the master painter makes his design, the outlines of which he sketches on paper with crayon, and then fills in the details with a brush and ink. Upon this design the pupils follow all the strokes of the brush with orpiment, distempered with water; and, to imprint the design upon the varnished article, they apply to it this design thus freshly traced, pressing lightly with the fingers everywhere over the design, in order that all the marks should leave impressions upon the work. Having taken off the paper they use orpiment again, but mixed in gum-water, or in water in which a little glue has been dissolved (where we use gum-water the Chinese use size), going over all the marks with a brush; then the design will not come off.

I have already said that the varnish employed by painters in varnish is called Koa-kin-tsi; it is this varnish which is used for a mordant in applying gold; also this varnish is used for distempering colors. To render the varnish more fluid they mix with it a little camphor, which they have previously crushed and mixed with some varnish; they make a paste of it which they knead or rub with a spatula a quarter of an hour or so; it is this paste of which they take a little to temper their colors. Their mordant is nothing else, as has been said, than the varnish Koa-kin-tsi, to which they add some orpiment; when the colors are well mixed they strain them through Che-tan-tschi; they take commonly a little at a time, perhaps an eighth of an ounce or so, enveloping it in Che-tan-tschi, and twisting the two ends with the fingers, they receive the color as it comes through on their fingers with which they are twisting it; they scrape it off on the palette, which is only a piece of bamboo split in two in the middle; often, before they are done, the paper bursts. They ought, as soon as the color begins to come through, to untwist the paper a little without slackening the hands, but with one of the disengaged fingers transfer the color as it exudes to the place where it is to be received, being careful not to open the paper; in this way the paper may usually be prevented from bursting.

If they wish the gold to have a high color, they mix vermilion with the mordant; after the application of the mordant they set the piece to dry in the workshop; about twelve hours is enough for the mordant to be dry enough for the application of the gold.

Gilding.—They have carefully prepared powdered gold in a shell, which they apply with brushes of Sée-mien; with these they rub the gold lightly over the place where there is mordant; brushing off the surface, they find the gold applied to the design. If they fear lest it may stick to places where they have not applied the mordant, on account of the varnish not being sufficiently dry, they crush some ball white, and with a bit of silk cloth they rub it lightly over the suspected places; after having well wiped the surface they boldly apply the gold upon the mordant.

Sometimes the painters do not put to dry in the workshop the pieces on which they have applied the mordant. They have a paper called Tchou-tchi, which is made of the pellicle which covers the joints of the bamboo; it is made in great quantity in China: the most of the books are printed on this paper; that which is used for the purpose now mentioned is very thin—the same which is used for books of gold-leaf. This they apply several times over the mordant, until hardly any trace of it remains; then they apply the shell gold, which adheres in greater quantity but with less lustre; for shading it is good, but elsewhere it is better to apply it in the other manner.

The Chinese use three kinds of gold, the Ta-tchi, the Tien-tchi, and the Hium-tchi. The Ta-tchi is ordinary gold; the Tien-tchi is pale gold; the Hium-tchi is made with silver-leaf to which they have given a golden color by exposing it to the vapor of sulphur. The Hium-tchi is not much used except for the edges of dishes, and sometimes for unusually pale shades; to gild the edges of vessels they pass the Hium-tchi through a sieve, and with the end of the finger, on which they have placed some of this powder, they apply it on the edges where they have just before applied some mordant without using any Tchou-tchi to take it up; this is so that there may be a large amount on those places which are most subject to wear; they do not care if the mordant does dull the gold.

When they have been over the article with the bunch of Sée-mien, charged with shell gold, sometimes a little gold adheres to the surface without being really attached; this they brush off by lightly touching it with the bunch of Sée-mien. If there are any places which they cannot reach with the bunch of Sée-mien, they apply the gold with the pointed end of the brush-handle.

To imitate mountains, and make sharp separations, they cut out a bit of Tchou-tchi according to the form which they wish to give the mountain; with the paper they cover the place of the mountain and pass the pale gold over the whole; it does not adhere to the places covered by the paper.

To imitate the trunks and branches of trees or the stalks of plants, after having laid on the first coat of gilding, they trace anew the places which they wish to be marked; and when the mordant has dried in the workshop twelve hours they go over it with shell gold. Ordinarily they use the red mordant, that is, that in which they have mixed vermilion instead of orpiment; the gold is thus made brighter in color.

White in varnish is obtained by mixing with varnish leaves of silver; only enough varnish is used to make a paste. As much varnish as will make the bulk of a pea is enough for twenty leaves of silver; they mix the leaves one after another; when all are mixed they add a little camphor, which makes the paste almost as clear as water. In place of silver-leaf, to be economical, the Chinese sometimes use some quicksilver, prepared in a particular manner. This is a secret in a single family. All other material than silver-leaf or the mercury thus prepared will blacken when mixed with varnish; silver makes the most beautiful white.

Varnish Colors.—For red they use Tchou-tche, which appears to be the mineral cinnabar. They can also use a lake made of carthamus-flowers.

For green they use orpiment, which they mix with indigo, which they call here Kouang-tien-hoa; it is true indigo and comes from the southern provinces.

For violet they use Tse-che, or violet-stone (Che means stone; Tse, violet); they use it to make opaque glass. They reduce this stone to an impalpable powder. They also use colcothar, or green vitriol calcined until it is red; to free it from saline matter they boil it in a large quantity of water. Varnish, they say, will not endure any salt.

Yellow is made with orpiment.

Colors mixed with varnish are not brilliant at once, but change after a time; the older they are the more beautiful they become.

When painters wish to lay on an unusually heavy coat of color they use Sée-mien instead of Tchou-tchi.

To clean varnished articles they use a piece of silk, like an old silk handkerchief; with this they dust off the surface by whisking it, not by rubbing; if, after this, there are still some dirty spots, they easily clean them by wrapping the finger in the handkerchief and rubbing them; if that is not enough, they may wet the end of the finger, still wrapped in the handkerchief, by touching it to the tongue; but it is best if possible to dust off the dirt with the wind made by using the handkerchief as a whisk, and if that will not do, pass the finger, wrapped in the handkerchief, through the hair, from which it will absorb a little oil, which is excellent for cleaning the varnished surface.

If the varnished article has been softened by being set too near the fire, it may be restored by leaving it out in the dew.

By exposing colors in varnish to the air, their brilliance is increased.

Shell gold is thus prepared: They roll a sheet of paper into a cone; in this they put the gold-leaf which is to be made into shell gold. When they have enough, they take a very smooth plate or porcelain platter; on this they pour a few drops of water in which they have dissolved a little glue; then they turn the gold-leaf on the plate, and with the ends of the fingers they rub the gold as if with a muller; the more they rub it the more beautiful it becomes. They wash it twice with slightly warm water, and put it away for use. This is the only way the Chinese have for preparing it.

From Father D'Incarville's memoir there is an interval of a century and a quarter to the next detailed account of oriental lacquer, this time by a British acting consul, Mr. John J. Quin, who in January, 1882, wrote from Tokio a paper of the highest interest on the subject; it is evident from what he says that the varnish must have been the same as that used in China; but the methods of using varnish were far more elaborate than those described by the Jesuit missionary. It is not improbable that D'Incarville gave only the simplest procedure, and that more intricate methods were in use; in fact, we know that such must have been the case. As described by Mr. Quin the processes are much more prolonged; but he only gives what was in his view the simplest practice. The following is condensed from his paper, using wherever possible his own words; but the necessary omissions have made it seem necessary to change the language in many places, that the meaning may be clear. Those interested may consult the original paper in the British consular reports.

Lacquer-trees of Japan.—The Rhus vernicifera, the lacquer-tree of Japan, is met with all over the main island, and also in smaller quantities in Kinshiu and Shikoku, but it is from Tokio northward that it principally flourishes, growing freely on the mountains as well as in the plains, thus indicating that a moderate climate suits the tree better than a very warm one. Since early days the cultivation of the trees has been encouraged by the government, and as the lacquer industry increased plantations were made in every province and district.

The lacquer-tree can be raised by seed sown in January or February; in ten years the seedling trees will average ten feet high, the diameter of its trunk two and one-half to three inches, and its yield of lacquer sufficient to fill a three-ounce bottle. The trees are set about six feet apart in the plantations.

A more common method is to cut off a piece six inches long and the thickness of a finger from the root of a vigorous young tree, and planted with one inch of the root above ground. In ten years these will make trees larger than the seedlings by about two-thirds and will yield nearly half as much more sap.

Lacquer plantations are only on hillsides and waste lands.

Collecting Lacquer.—The trees are tapped once in four days for twenty-five times in one season from June 1st to October 1st. The cuts are each about an inch and a half long and are from near the ground to as high as a man can reach about six inches apart vertically, but diagonally, not one above another. Branches one inch or more in diameter are also tapped. The tree is thus destroyed in one year. When cut down the branches are cut up and tied in bundles and steeped in water for ten days, after which the lacquer which exudes from them is scraped off; this is called Seshime, or branch lacquer; but this name is also applied to purified and filtered raw lacquer obtained from the trunks of the trees, as has been fully explained by Rein, and in the following directions, where the term "branch lacquer" is used, this purified raw lacquer is undoubtedly meant. The confusion arises from the same name, se-shime, being applied specifically to branch lacquer and generally to purified raw lacquer. Only a small amount of true branch lacquer is obtained, and it is of poor quality; while from Mr. Quin's specifications it is plain that most of the varnish used was what he calls "branch lacquer," really the ordinary se-shime.

Shoots sprout up from the roots of the trees which have been cut down, and grow rapidly.

The best lacquer for transparent varnish comes from large trees, one to two hundred years old. These are, however, rapidly disappearing. These large trees were formerly valuable because wax was made from their berries, and this was used for lighting; the introduction of kerosene has destroyed this industry.

True branch lacquer becomes extremely hard when once dry, but used alone will not dry under some twenty days, so that now, when time is an object, the pure sap is very little used. The price of pure branch lacquer is, owing to the difficulty of drying, only 70 per cent. of ordinary good lacquer.

Evaporating in the Sun.—In preparing all lacquer—from the crude lacquer to the various mixtures—the principal object is to get rid of the water that exudes from the tree with the sap. To effect this, it is exposed in broad flat wooden dishes, and stirred in the sun. This, however, alone will not cause the original water to evaporate, so from time to time, ordinarily about three times in the day, a small portion of clear water is stirred in, say one per cent. each time, for a couple or three days, according to the heat of the sun; all the water then evaporates together. No lacquer will dry until this process has been gone through. If the lacquer is old, i.e., has been tapped a long time before using, it is much more difficult to dry. In such cases a portion of fresh lacquer is added to the old by the wholesale dealers; or else the manufacturers, instead of water, sometimes mix saké (rice beer) or alcohol to quicken it.

A very remarkable property of lacquer should be mentioned. If crude lacquer, which is originally of the color and consistency of cream, is exposed to the sun a few days without adding water, it loses its creamy color, and becomes quite black, or nearly so, but also becomes thinner and transparent, or rather translucent, as can be seen when it is smeared on a white board. It will not now, however, dry if applied to an article, even if kept a month or more in the damp press. But if water is mixed with the lacquer which has thus been exposed and become black, it at once loses its black color and its transparency, and becomes again of a creamy color, though slightly darker, as if some coffee had been added, than at first. After evaporating this water it can then be used like any ordinary lacquer, either alone or in mixtures, and will dry in the damp press, during which process it again turns black.

Black Lacquer. Black lacquer is made by adding to crude lacquer about five per cent. of the tooth-dye used by women to blacken their teeth, which is made by boiling iron-filings in rice vinegar, and exposing it to the sun for several days, stirring the mixture frequently until it becomes a deep black.

What lacquer-workers have found their greatest stumbling-block is the difficulty of obtaining a clear transparent varnish.

What is called a transparent varnish is really black to the eye, and requires grinding and polishing after application before it presents a brilliant surface, becoming also much lighter after a little time.

Perilla-oil.—Only the cheapest and commonest kinds of lacquering are done with lacquer mixed with oil; the oil used is that obtained from the plant called Ye (Perilla ocymoides). These do not admit of polishing. Lacquer is prepared in this way, sometimes as much as fifty per cent. of oil being added, after which water is added and the whole evaporated again in the sun; and this is used to mix with colors to make enamel paints. It is said that vegetable colors cannot be used with lacquer, being in some way destroyed by it. The workmen have never been able to produce white, purple, or any of the more delicate shades. Vermilion, oxide of iron, and orpiment are the principal colors.

For preparing the surface to be lacquered various priming coats are used; cavities are filled with a sort of cement made by mixing chopped hemp fibre with lacquer; joints are covered with hemp or silk cloth, which is pasted on with a mixture of wheat-flour paste and branch lacquer, or instead of wheat-flour paste, rice-flour paste is used, but is not as good. A mixture of whiting and liquid glue is used for a surface coat on cheap articles. Surfacing compounds, like our rough-stuff, are made by mixing lacquer with finely powdered brick-dust, or powder made of some fine clay which has been burned. They have rubbing-stones of four degrees of fineness; also they use scouring-rushes (Equisetum) in place of sandpaper; they use several grades of charcoal for polishing, or rather for rubbing before polishing; for a polishing-powder they calcine deer's horns and reduce them to a very fine powder.

The process of plain lacquering may be thus described:

1. The article to be lacquered is first carefully smoothed.

2. The wood is slightly hollowed away along each joint, so as to form a circular depression.

3. The surface of the whole article is then given a coating of

branch lacquer, and the article set to dry in the damp press for about twelve hours. This press is air-tight, made of wood, with rough unplaned planks inside; these are thoroughly wetted with water before the articles are put in to dry. Lacquer absolutely requires a damp closed atmosphere for its hardening; otherwise it will run and will always remain sticky. The time of drying is from six to fifty hours, according to the kind of lacquer and the time of year.

4. The hollowed portions are filled with a mixture of finely chopped hemp, rice paste, and branch lacquer; this is well rubbed in with a wooden spatula, and the piece is set in the damp press to dry for at least forty hours.

5. Over this is spread a coating made of two parts of finely powdered burnt clay and one and a half parts of branch lacquer, in with just enough water to mix the clay to a paste; it is then set to dry for twelve hours.

6. The next process is to smooth off with a rubbing-stone any roughness of the preceding coats.

7. The article is then given a coating of a mixture of wheat-flour paste with branch lacquer, over which is stretched a hempen cloth, great care being taken to spread it smoothly and leave no wrinkles or perceptible joinings; and it is then again inclosed in the drying-press for twenty-four hours.

8. After taking the article out of the press all inequalities in the cloth—which has now under the influence of the lacquer become harder than wood—are smoothed down with a knife or with a plane.

9. Next, a coating like No. 5 is applied with a wooden spatula, to hide the texture of the hempen cloth, and the article is again put in the press for twenty-four hours.

10. Next, a coating is given of one part of powdered burnt clay and two parts of branch lacquer, applied with the spatula, after which the article is inclosed in the drying-press for twenty-four hours.

11. Next, a coating is given of one part of powdered burnt clay and two parts of branch lacquer, applied with the spatula,

after which the article is inclosed in the drying-press for twenty-four hours.

12. Next, a coating is given of one part of powdered burnt clay and two parts of branch lacquer, applied with the spatula, after which the article is inclosed in the drying-press for twenty-four hours.

13. Next, the article is given a coating of equal parts of powdered brick and burnt clay, with which is mixed one and one-half parts of branch lacquer, and the drying process is repeated for twenty-four hours.

14. Next, the article is given a coating of equal parts of powdered brick and burnt clay, with which is mixed one and one-half parts of branch lacquer, after which it is set to dry for at least three days.

15. The surface is next ground smooth with a fine hard rubbing-stone.

16. A hardening coat of branch lacquer is given with a spatula, and set to dry for twenty-four hours.

17. A coat like No. 5 is applied with a spatula, and set to dry for twenty-four hours.

18. When thoroughly hardened the surface is ground with a fine hard rubbing-stone.

19. Next, a thin coating of branch lacquer is applied with a spatula, and the article is set to dry for twelve hours.

20. A coating of ordinary lacquer is then applied with a flat brush, and the article is set to dry for twenty-four hours.

21. The surface is then ground smooth with a kind of charcoal having a rather rough grain; it is made from the Magnolia hypoleuca.

22. A thin coating of branch lacquer is given with cotton wool—old wool being preferred because less likely to leave hairs behind it—and rubbed off again with soft paper, after which the article is set to dry for twelve hours.

23. A coating of black lacquer is then applied, and it is set to dry for twenty-four hours.

24. The surface is rubbed smooth with very fine and soft charcoal.

25. A coating of black lacquer is then applied, and it is set to dry for twenty-four hours.

26. The surface is rubbed smooth with very fine and soft charcoal.

27. The surface is partly polished with finely powdered soft charcoal, applied with a cotton cloth.

28. A coating of black lacquer is then applied, and it is set to dry for twenty-four hours.

29. The surface is now polished with an equal mixture of finely powdered burnt clay and calcined and powdered deer's horns, applied with a cotton cloth and a little oil.

30. A coating of branch lacquer is next given, applied with cotton wool very thinly, and the article is inclosed in the drying-press for twelve hours.

31. The workman dips his finger in oil, and rubs a small quantity of it over the surface, which he then polishes with deer's-horn ashes, applied with a cotton cloth till a bright surface is obtained.

32. A coating of branch lacquer is applied as in No. 30, wiped off with soft paper, and set to dry for twelve hours.

33. The oil is applied as in No. 31, and then a final polishing with deer's-horn ashes, given with the finger to the surface, which now assumes the most brilliant polish of which it is susceptible.

For articles which are liable to get rubbed, such as scabbards, these last two processes are repeated seven or eight times, the surface getting harder at each repetition.

In describing the above processes the minimum time for drying has in each case been given, but for the first twenty-five processes the longer the article is kept in the press the better. From the twenty-eighth process to the finish it is better not to greatly exceed the times mentioned.

In making articles ornamented in gold lacquer the first twenty-two processes are executed, and at this stage the object is ready to receive the decoration.

Transfer of Designs.—The picture to be transferred to the article is drawn on thin paper, to which a coating of size made of glue and alum has been applied. The reverse is rubbed smooth with a polished shell or pebble, and the outlines very lightly traced in lacquer, previously roasted over live charcoal to prevent its drying, with a fine brush made of rat's hair. The paper is then laid, with the lacquer side downward, on the article to be decorated, and is gently rubbed with a whalebone spatula wherever there is any tracing, and on removing the paper the impress may very faintly be perceived. To bring it out plainly it is rubbed over very lightly with a piece of cotton wool, charged with powdered tin or the powder of a hard white stone, which adheres to the lacquer. Japanese paper being peculiarly tough, upwards of twenty impressions can be taken off from one tracing; this tracing does not dry, owing to the lacquer used for the purpose having been partially roasted, and can be wiped off at any time.

The next process is to trace out the veining of the leaves, or such lines to which in the finished picture it is desired to give the most prominence, and these lines are then powdered over with gold-dust through a quill. The article is then set to dry for twenty-four hours in the damp press. The outline is now drawn carefully with a rat's-hair brush over the original tracing line with a mixture of black lacquer and branch lacquer. The whole is then filled in with this mixed lacquer applied with a hare's-hair grounding-brush. Gold-dust is scattered over the lacquered portion, and the article is set to dry for twenty-four hours. Another thin coating of this mixed lacquer is again given to the gold-covered portions, and the article set to dry for twelve hours.

Next, a coating of black lacquer is applied over the whole surface of the article, which is set to dry for at least three days. It is then roughly ground down with coarse charcoal, the surface dust being constantly wiped off with a damp cloth till the pattern begins to appear faintly. Another coating of black lacquer is then given and the article set to dry for thirty-six hours. It is again ground down with coarse charcoal as before, this time until the pattern comes out well. The ensuing processes are the same as have been described from No. 28 to No. 33 inclusive, for plain lacquer.

Another Method of Finishing.—Another method consists in first thoroughly finishing the piece in the manner first described; then a tracing is applied to the surface in the manner described for gold lacquering; the outline is carefully painted over with a fine brush of rat's hair and then filled in with a hare's-hair brush, using branch lacquer mixed with an equal weight of bright red oxide of iron. Over this surface gold-dust is scattered with a brush of horse's hair until the lacquer will not absorb any more. The article is then set to dry for twenty-four hours. A thin coating is next applied over the gold of the finest and most transparent lacquer, and set to dry for twenty-four hours at least. It is then most carefully smoothed with soft fine charcoal, and finally polished off with finely powdered burnt clay and a little oil on the point of the finger, until the ornamental portion attains a fine polish. The veining of leaves and the painting of stamens, etc., of flowers, or such other fine work, is now done with a fine rat's-hair brush charged with branch lacquer mixed with red oxide of iron; for this special use the lacquer has been allowed to stand, after mixing, about six months, which causes it to be thicker and less disposed to run, so that it will make fine lines, and it will besides stand up more. Over this fine gold-dust is scattered with a horse's-hair brush, as before, and the article set to dry for twelve hours. Some fine transparent lacquer is then applied to a piece of cotton wool, and rubbed over the whole surface of the box or other article, and wiped off again with soft paper. It is set to dry for twelve hours, after which it is polished off with deer's-horn ashes and a trifle of oil. If a very fine surface is desired, this last lacquering and polishing is repeated.

Lacquer on Metal.—For lacquering on iron or copper, brass or silver, the metal is polished, then given a coat of black lacquer, and put over a charcoal fire and the lacquer burnt on to the metal until all smoke ceases to escape. The fire must not be too fierce, and the metal must not be allowed to get red-hot, or the lacquer turns to ashes. After it is baked quite hard the surface is rubbed smooth with soft charcoal; these operations are repeated three or four times, until a good foundation of lacquer has been obtained. The subsequent treatment is exactly such as has been already described, only that the lacquer may be either dried in a damp press in the ordinary way or it may be hardened by baking over the fire.

When work is required in a hurry the workmen sometimes put a pan of hot water, heated by a charcoal fire, into the press; the steam thus generated dries in an hour or two the lacquer which would ordinarily take twenty-four hours. But lacquer thus treated loses its strength and is never very hard.

Treatise by Dr. Rein.—Some time after the publication of Mr. Quin's report, Dr. J. J. Rein, professor of geography in the University of Bonn, spent some time in Japan, at the expense of the German government, studying the industries of that country. The results of his investigations were published in a sumptuous volume in 1889; and this book, called "Industries of Japan," contains the most elaborate and detailed account of the art of lacquering that has yet appeared. The book has been translated into English and may be found in almost any large library; hence it has not been thought best to attempt to give any complete review of its contents. In general it may be said that it agrees with Mr. Quin's report; and the following extracts are given to supplement and complete the account already transcribed. These extracts are not to be understood as a continuous statement from their author, but are chosen to explain what seems to the present writer the most important points.

Raw Lacquer.—The raw lac is called Ki-urushi; it must be purified before it can be used at all. It is first pressed through cotton cloth, and is then called Ki-sho-mi, or purified raw lac. It then contains from ten to thirty-four per cent. of water, which can be expelled by stirring in the sun or over a slow fire, but especially by a water-bath. It also contains 1.7 to 3.5 per cent. of nitrogenous matter, apparently a proteid; and 3 to 6.5 per cent. of gum, similar to gum arabic. It contains from 60 to 80 per cent. of lac-acid or Urushi acid, which is the characteristic ingredient.

Traces of oil are sometimes found; the tapster oils his knife and his spatula or metal spoon to prevent the lac from sticking to them. The lac-acid is soluble in alcohol, ether, chloroform, etc.

The Ki-sho-mi, or purified raw lac, if deprived of water, is a gray or brown, syrupy sticky liquid; it will absorb water and is thereby made into a jelly, which when painted on wood dries very quickly. Lac may be thinned by heat, but is usually thinned by the addition of camphor. This is pulverized and added, undissolved, to the lac, in which it dissolves.

Lac dries best in a damp atmosphere at a temperature from 10° C. to 25° C. or at most 30° C.

Lacquer Dries by an Enzymotic Ferment.—The lac-acid extracted by alcohol does not dry; it requires the presence of the proteid and water; and if heated over 60° C. (to a temperature which coagulates albumen) it loses its power to dry. According to Korschelt (Chemistry of Japanese Lacquer, Trans. Asiatic Society of Japan, Vol. XII) the proteid acts as a ferment upon the lac-acid and causes the latter to oxidize, which causes it to become hard. This oxidized lac-acid is insoluble in all the solvents of lac-acid, and is not acted on by either acids or alkalies.

Ki-sho-mi is ground for some time in a shallow wooden tub, to crush its grain and give it a more uniform fluidity. It is then pressed through cotton cloth or hemp linen; it is then called Se-shime, which is a purified, filtered, and evenly flowing raw lac. It is ready for sale in this condition, but not for use; it must be deprived of its water by evaporation. This is done by evaporation in the sun, or by moderate heat over a coal fire. The Se-shime is poured into shallow pans, twenty to forty inches in diameter and an inch or an inch and a half deep, and stirred constantly with a flat paddle. If the wooden pan is heated by holding it above a fire, the operation takes several hours; if without fire, it may take sixteen or eighteen hours. After this it is again filtered through cloth. About twenty varieties of lacquer are made from Se-shime; some of these are from new lacquer of choice quality, depending on the size and vigor of the tree and the season, but most of the differences are made by admixtures of other substances, such as gamboge, vermilion, and especially an oil, very much like linseed-oil, made from the seeds of a cultivated annual plant, the Perilla ocymoides, a labiate plant which is sown in April, blossoms about the end of September and is ripe two weeks later, by the middle of October. It is extensively grown in China and Japan.

The general rules to be observed by the lacquerer are as follows:

1. Every coat must be laid on evenly and then gone over crosswise with the brush or spatula, first in one direction and then afterward in the other.

2. No new coat must be put on before the last one is dry.

3. It can best be determined when a smooth surface is dry by the condensation of the moisture breathed upon it.

4. Only the groundwork can be dried in the open air or direct sunlight, and then only when the coating contains very little or no lac admixture.

5. The drying of all genuine lacquer coats must take place in the damp, unwarmed amosphere of a chest, cupboard, or chamber. In order to secure this the chest is laid on its side and washed with a wet cloth. Then the lacquered articles are put in, and the cover, which has been washed also, is closed. The drying cupboard with shelves is treated in the same way.

6. Such an arrangement serves to keep off draughts of air, dust, and light during drying.

7. Every fine, finishing lacquer-varnish before it is laid on must be pressed once or twice through a fine porous but strong paper, by turning at both ends in opposite directions. Moderately warmed, it flows more freely and hastens the process.

8. After almost every new coating, according to its nature, comes rubbing off with a rubbing- or polishing-stone, or with magnolia charcoal, or with burned deer's horn (in the first two cases of course with the addition of water), according as the operation follows groundwork or a later coating.

9. The carefully lacquered article when finished must not in any way reveal the make or material of its framework, must be free from accidental unevennesses, cracks, and spots, must have a mirror-like surface and not change in drying nor by heating with warm water. Finally, when breathed upon the moisture must disappear quickly and evenly from the outside toward the centre, as on polished steel.

Brilliance Developed by Age.—Professor Rein further describes some of the various methods employed in decorating lacquered articles with gold and colors; these methods are more elaborate and prolonged than any ever practised in America or Europe. This is partly due, no doubt, to the fact that some of these lacquers, especially the finer and more transparent ones, although they appear to dry in a few days, or weeks at most, do not acquire their full perfection and beauty for a long time; from Father D'Incarville to the latest writer, all agree that one or more years are required for the complete development of the brilliance of the film after it has been applied. The present writer has two friends who were for some years professors in the University of Tokio, and who were told and believe that fine specimens of lacquered ware take from twelve to twenty years in finishing. These gentlemen also say that when at intervals it was necessary to have their desks varnished, their hands were poisoned by contact with this freshly varnished surface. Broken fragments of lacquered ware show a great number of layers; and there can be no doubt that the most valuable and essential secret of the lacquer-workers is their unlimited patience, which, with the cheapest labor in the world and the readiness on the part of wealthy collectors, both native and foreign, to pay for really fine lacquered articles sometimes more than their weight in gold, make it possible to get results not attained by our more hasty methods.

Amount of Lacquer Produced.—Both Mr. Quin and Professor Rein agree that the price of raw lacquer in Japan in 1880 was about sixteen dollars a gallon, wholesale; and from investigations made by the latter and from official Japanese government reports it appears that the total annual product of lacquer in

Japan was from 8,000 to 13,000 imperial gallons. Its specific gravity is about the same as that of water. Quin says a tree will produce enough lacquer to fill a three-ounce bottle; Rein estimates an average yield much smaller, from one to two ounces; while W. Williams, in "The Middle Kingdom," gives twenty pounds to a thousand trees, or only one-third of an ounce to the tree. No doubt the yield varies in different regions. The trees are a regular crop, being set out by the farmer in plantations, on land otherwise waste, and require ten years to mature; then the owner sells the whole crop of trees—the "stumpage," as lumbermen say—to a contractor, who in the course of a single summer destroys this ten years' growth for the sap it will produce; and he has the dead timber to sell for firewood; after which the land is again set out with trees for another ten years' crop. As an acre will support a thousand or twelve hundred trees, it may produce from four to ten gallons of varnish in ten years.

The most noticeable thing about this matter is the small amount of the annual product. At the time of writing this (in 1903) a single American company (the International Harvester Company) are using 375,000 to 400,000 gallons of varnish annually, or thirty times as much varnish as the total yield of lacquer in Japan; and this is a very minute part of the varnish used in this country. On the other hand, sixteen dollars a gallon is more than any one pays for any considerable amount of varnish in America or Europe; it is not likely that ten thousand gallons of varnish is sold in America, Great Britain, all Europe, and all their dependencies, at half of sixteen dollars a gallon, in a year.

Our varnishes, of all sorts, dry best in a warm, light, dry room; but these oriental lacquers dry best in a cold, wet, dark closet. This is an extraordinary thing; it is now universally believed that lacquer dries by the agency of a ferment. It is to be remembered that there are two sorts of ferments, one which appears to be some sort of a living organism, such as yeast; another, such as diastase, which converts starch into sugar, is not an organized ferment, and ferments of this sort are called enzymes. One of these enzymotic ferments is present in this oriental lacquer, and it is through its action that the film is oxidized and becomes hard. Enzymes are very sensitive to heat, whence it is necessary to dry this lacquer at a low temperature and in a damp atmosphere. Attempts have been made by chemists to study the ferments of this lacquer, and the surprising and interesting statement has been recently published that its ash contains a large percentage of manganese. This is very singular; if a drying-oil was used in the mixture, it is possible that a manganese drier had been added, but there is nothing to warrant such an inference, which was certainly not believed by the investigator.

In conclusion, the present writer wishes to disclaim any original knowledge of the subject or wish to be regarded as an authority. It is said, on what appears to be good authority,—in fact, the reports come from many sources and through a long time,—that manila and similar varnish-resins have long been imported into China; and if we ever get a complete knowledge of the matter we shall very likely find that oleo-resinous varnishes, made from these resins and tung and Perilla oils, have also been long known. The lacquer, being at once the most valuable and the most remarkable of varnishes, is the only one which has attracted attention; but this is merely a speculation.

CHAPTER XVII.

PROTECTION OF METALS AGAINST CORROSION.

From early times the use of paints and varnishes to prevent the rusting of metals has been known to be of importance. Brass does not, under ordinary conditions, rust deeply, but it tarnishes quickly and needs some kind of a lacquer to preserve its surface; but iron and steel are easily corroded, and the corrosion goes on more rapidly as it progresses. Metallic iron does not exist in any appreciable quantity in nature; the principal ores of iron are hematite, which is the anhydrous sesquioxide, and limonite, much more abundant than the former. It is evident from this that there must be a great affinity between iron and oxygen, and since most of the ore contains a little water, not as a mixture, but in chemical union, it is plain that the presence of water is favorable to this combination of oxygen and iron. This combined water is so firmly united to the oxide that it can be driven off only by prolonged heating to redness, but the oxygen is so strongly bonded to the iron that it is only removed by heating the ore to a white heat in intimate contact with white-hot carbon, which has such an intense attraction for the oxygen that it is able to take it away from the iron which is left in a molten condition from the effect of the intense heat necessary for the decomposition of the ore. Such being the attraction between metallic iron and oxygen, it is not surprising that they should readily combine, even at ordinary temperatures. Their existence apart is contrary to natural law, and sooner or later they will get together in their natural union. All we can hope to do is to prolong their separation as much as possible. It is said that iron will not rust in perfectly dry air, but this is not of much practical importance because there is no such thing, except as it is chemically prepared and kept in sealed apparatus in a laboratory. It does not rapidly rust in the comparatively dry air of a desert; but nobody lives in the desert to use it; yet these facts clearly show that moisture is a great help to rust.

Conditions Favorable to Corrosion.—The air not only contains moisture, but also a small proportion of carbonic acid, and it has been clearly demonstrated that this also is an important aid to corrosion. Since iron in its various forms is the most useful of all metals, it is naturally used in greatest abundance in cities, and the air of cities always contains, from the burning of coal, an excessive amount of carbonic acid and an appreciable amount of sulphur in various forms, chiefly as sulphurous and sulphuric acid, which are intensely corrosive, and on the seacoast the air also contains sea-water spray floating in it, which greatly increases its corrosive action. It is well known that heat accelerates chemical action, hence the hot, moist, sulphurous, and strongly carbonic gases ejected from a railway locomotive, or from any other coal-burning furnace, are most powerful as corrosive agents, and conversely the cold dry air of northern latitudes, away from the seacoast or other large bodies of water, has the least action; in such situations, indeed, in the winter the effect seems to be so slight as to be hardly worth considering.

Such, in brief, are the conditions which favor corrosion, and from their consideration it is clear that what is necessary to prevent corrosion is some means to prevent the access of air and moisture. It is attempted to do this sometimes by embedding the metal in cement or concrete. This is to be considered good practice, because the cement is not only nearly impermeable, but it is also strongly alkaline, and of course the free alkali prevents the access of acid to the metal.

Protection by Cement.—It is, however, possible to overestimate the completeness of this protection, for it is sometimes asserted that such cement or concrete is really impermeable, which of course is not the case. Even neat Portland cement is somewhat porous, and in fact there are testing-machines for measuring the porosity of plates of cement, so it is clear that both air and water, that is, gases and aqueous solutions, may circulate, more or less slowly, through it, and as concrete is practically used it contains numerous cavities which, while not affording continuous channels, appreciably lessen its impermeability.

Important engineering works are often built of concrete reinforced by steel wires, rods, or beams, sometimes by riveted steel frames, but depending largely on the strength and rigidity of the cement. It is an important matter to know whether the steel in such a structure is indestructible or not. As to that the writer of this does not propose to express any decided opinion; but objections are always in order, if for no other purpose than to suggest desirable precautions. In the first place, it may be observed that the design of the builder is to make an artificial stone. Either this must be monolithic or it must have expansion-joints. If the former, it must be remembered that it is difficult to make a really monolithic structure of considerable magnitude; for concrete poured fresh on a surface of similar concrete which has been allowed to stand a day or so, or sometimes only overnight, does not form a strong bond to it, even when the greatest care is taken, and the block thus formed will separate along the surface where the interruption in work took place, if any great stress be applied.

Considerations Relating to Reinforced Concrete.—To make a really monolithic block the work of adding the concrete must be continuous, and this is difficult to insure on very extensive work lasting perhaps for weeks. The steel may be so placed as to strengthen these joints, but it must not be forgotten that the strength depends chiefly on the steel at such places, and also that, although such a joint may be water-tight, it is a place where there is a tendency for the concrete block to crack from changes of temperature. Steel thus embedded can change in temperature only very slowly, but it does change with the mass, and its rate of expansion and contraction may be slightly different from that of the concrete.

It may be conceded that if air and moisture are kept from the metal it will not rust; but it is hard to be sure that water is kept out of such a structure, and if the steel rusts it not only loses its strength, but exercises a most destructive action on the surrounding concrete, tending with immense force to split it to pieces, because of the increase in bulk of the iron. If we were selecting a building stone, would we choose one which was traversed in every direction by streaks or long crystals of a mineral very different in chemical and electrical qualities from the matrix? It may be doubted. Quarrymen would not regard such a rock as sound, and would expect to find it split in pieces or disintegrated by the action of the weather. It seems reasonable, then, to expect that great care is necessary, in building such structures, to insure continuity, and especially to prevent the soaking of the whole mass with water from rain and melting snow; for concrete often has voids and porous places, and little attention to making its surface water-proof is usually given. Above all, provision should always be made for drainage, and this is too often neglected; the whole mass is soaked and sodden with water which lies there month after month.

Expansion-joints.—Some of these objections do not apply to blocks of reinforced concrete put together with expansion-joints. In these structures it is clear that the atmospheric water will have access to the joints, and in cold weather will by freezing tend to injure them unless it can be kept out by some elastic water-proof packing or can be perfectly drained; perhaps both precautions are not too much. It is difficult to permanently close a crack in concrete, and it may be doubted if there has yet been built a large mass of it, without expansion-joints, which has not cracked. These cracks naturally lead to weak places in the interior and conduct water and air to these unknown and inaccessible recesses, perhaps to hasten the destruction of the inclosed steel on which the strength of the structure depends.

Should the steel in such structures be painted? The objection commonly made is that in order to get the utmost advantage from the use of the steel, we must have the concrete adhere perfectly to it, so that there shall be no break in continuity between the cement and the metal, and the latter shall be a part of the concrete in the same sense that the broken stone is. Is this possible? The fragments of broken stone are of somewhat similar nature with the cement. Their elasticity and rate of expansion is the same; they exist in little isolated pieces, not in long threads or flat plates, and their rough surface and irregular shape are perfectly adapted to the adhesion of the matrix. It is not so with steel. It is frequently said experiment has shown in a testing-machine that cement adheres to iron with a force equal to its own cohesion, and this may be correct if proper care is taken to make it a direct pull. But probably every one has seen cement part from a steel surface without much resistance, even if the surface was specially prepared for it. There is not much difficulty in rattling the dried cement off a shovel, for instance; and it is quite likely that in any case where the enormous elasticity of steel comes into play—and it is because of its strength and elasticity that it is used—the so-called bond which exists between the cement and the metal is of very little account. This bond is sometimes spoken of as though it were something mysterious and sacred, but it may be doubted if cement sticks to iron in any different way from what anything else does or from what cement sticks to anything else.

In these days of woman-suffrage we hear much discussion as to whether marriage is a sacrament or a civil contract. I am of the opinion that the bond between cement and steel has more likeness to a civil contract than it has to a sacrament.

A definition of this bond would tend to a clearer conception of the whole matter, and it might then be found that an elastic and water-proof film between the metal and the cement which would lend itself a little to the differences in expansion was a source of strength and permanence rather than weakness. A subject like this is too important and too intricate to be approached with a feeling of prejudice and a determination to settle the matter ex cathedra. We have not yet got to the last word about reinforced concrete; it is very true that time and use are the final test, and that some of the earlier structures are still in good condition, but the earlier structures were built by men who were in some sense inventors and experimenters, and the work of an enthusiast is likely to be much more carefully done than that of a man who works by a formula.

Asphaltic Cement.—A really impermeable cement is one made of asphaltum applied in a melted condition; when of suitable composition and sufficient thickness this seems to be as nearly perfect a protection as anything which has been devised. Coal-tar pitch, which resembles asphaltum in appearance, is usually an acid substance and should not be used for these purposes, and it is not to be forgotten that asphaltum is mixed with all sorts of things, some of which are not injurious if not used in too great quantity, but the best of which usually so dilute the asphalt, which is the real cementing material, as to lessen its permanence.

To be of any value as a cement asphaltum must be tough and somewhat flexible, a quality usually obtained by using a naturally soft asphalt, or by tempering a harder asphalt with a heavy mineral oil; in either case the elastic or softening ingredient tends to be removed by atmospheric action, and still more by the effect of the weather or of water, and it is necessary to have a considerable thickness of cement over the metal, not less than an inch, and better two or more inches, when efficient protection may be reasonably expected. Such an asphaltic cement is not only tough and flexible, but it is also viscous. It will, especially in warm weather, flow slowly. This naturally prevents its use in places where it can run off. It is used for covering railway-bridge floors, and when used in sufficient quantity and with a reasonable appreciation of its properties satisfactory results have been attained. An important use for material of this sort is in coating water-pipe, a subject which will be treated as a separate topic. These methods deserve fuller treatment, especially the use of Portland cement, but at the present time there is but little accurate knowledge and especially hardly any which has been tabulated or otherwise made accessible on the subject of hydraulic cement for such use, and the making of serviceable mixtures of asphalt is in the hands of the great asphalt paving companies, who do not make it known, so that this must be left for some better-informed writer in the future.

Thinness of Films.—We come, then, to the problem of protecting metal from corrosion by the use of films of varnish and paint. The statement of the problem involves naming its greatest defect, which is that films are depended on for more or less permanent protection, and these films are only one or two thousandths of an inch in thickness. They are, therefore, easily scraped off or removed by any sort of abrasion. They are not very hard and are easily punctured, and if they are at all porous the pores, which will naturally be at an angle to the surface of the film, will extend through it because the distance is so little. If the matter is fairly considered, it seems almost preposterous to apply a film one or two thousandths of an inch thick to protect a steel plate or beam an inch or more in thickness in a situation where the uncoated metal would be destroyed in a short time, yet this is what is constantly demanded, and it is also asked that this material should be such as may be applied by unskilled labor and to any kind of a surface. It is a wonder that any favorable results are reached, yet they must be or the varnishes and paints would not be used.

Paint is Engineering Material.—Protective coatings, as applied to structures designed by engineers, are engineering materials, just as much as are the plates and beams to which they are applied. When an engineer designs a structure, he makes it usually from three to five times as heavy as the load actually requires, "for safety"; really this factor of safety is so large chiefly to provide for future deterioration, and a part of this excess of metal is added to secure the rest of it against rust, which is exactly what the paint is used for; hence the latter is fully as much engineering material as the steel which it covers, and deserves just as careful and serious consideration from the engineer—which it seldom gets. Part of the indifference to the subject is due to the fact that the engineer feels that he is rather ignorant of the matter and concentrates his interest on steel, of which he thinks he knows a great deal, though it may be suspected that the chemists in the steel-works have their own doubts about even that; but at any rate he has books of tables of figures relating to steel, and these are a source of satisfaction. The imaginative, the mathematical, the constructive part of engineering is and must always be a delight to the mind of the engineer, and is essentially different from that part which has to do with the qualities of materials, which are best understood, and even then only imperfectly known, by the experts who make a business of their manufacture.

Protective Coatings not Necessarily Decorative. — It has already been said that varnish and paint are used both for decorative effect and for protection of the underlying materials, and as the decorative effect is the more conspicuous, most people regard that as the primary quality; and when we speak of protective coatings the idea of decorative effect underlies, in their minds, the whole matter, perhaps unconsciously. By the very term used it is, however, eliminated. The decorative effect has absolutely nothing to do with the subject. Fortunately this condition, that no attention whatever shall be paid to decorative effect, can in most cases be enforced, because such effect may be reached by decorative painting over the protective coating, not only without injury, but in most cases with positive benefit to the latter. This is an important consideration, for it enables us to use materials which are quite unsuited for decorative use. For example, a paint or varnish as commonly used must dry "dust-free," i.e., so that dust will not stick to it, in about twenty-four hours, or less, because every hour adds to the danger that the beauty of the surface will be destroyed or injured by the adhesion of dirt, insects, etc., and this quality of quick drying is almost always obtained by the excessive use of driers which, as has been already explained, greatly lessens the durability of the compound, or else by the use of too large a proportion of resinous matters, which makes a brittle coating which cracks with changes of temperature, or too much volatile solvent is used, which diminishes the proportion of cementing material and produces a film which is lacking in coherence. If, on the other hand, we may leave out of account the looks of the paint or varnish, it is clear that we are at liberty to use anything which will add durability and impermeability to the film, which, in most cases, may be allowed a long time to dry and may have a comparatively rough and wrinkled surface. Thus, the members of a bridge are usually made up several weeks before erection, and a first coat has all this time to dry and harden; then it is painted after erection, and in most cases this coat may have all the time necessary. Probably in most cases the next coat will not be applied for some months, and in any subsequent painting the use of a slow-drying paint does not interfere with the use of the structure. Of course there are considerations which prevent the use of non-drying or too-slow-drying materials: they are liable to be rubbed off or even removed by the action of the weather; it is desirable to have a paint or varnish which sets within a reasonable time, say a day or two, but it may be allowed to dry slowly after that, taking up its last portions of oxygen only after a long period, and it is films of this nature, which show a continually increasing reluctance to oxidize, which have the greatest permanence. To exhibit a very smooth surface a paint or varnish must contain a considerable proportion of resinous matter; and while a certain amount is highly desirable, because it acts as a flux and prevents the formation of pores, a quantity sufficient to give a hard and very lustrous surface causes a lack of elasticity which may be the occasion of cracks in the coating, but a film intended only to protect against corrosion may have exactly the most desirable ratio of ingredients. Decorative paints must be made with certain pigments, and sometimes these are the cause of deterioration; but an injurious pigment should be excluded from protective coatings, which should contain only the best and most suitable compounds for the purposes for which they are made.

The preparation of the surface to which the protective coating is to be applied is a subject the consideration of which naturally precedes that of the material itself and of the method of its application. A great many years of experience and observation, and of consultation with painters and with engineers, have convinced the writer that paint and varnish adhere to a metal surface in the same way that other things do, and that the same conditions which favorably influence the adhesion of other coatings are desirable in the use of these substances; also that, making due allowance for the impermeability of a metallic surface as compared with a wooden one, the same principles which govern their application to all other surfaces apply to their use on iron and steel. Such statements as the foregoing will not probably appear to the disinterested and speculative reader to be unreasonable, much less revolutionary and inimical to all industrial progress, and he cannot fail to be interested in knowing that not only the ordinary contractor but the great steel companies (who naturally ought to be interested in the permanence of their products) regard an engineer who tries to adapt these maxims to practical work as a visionary theorist, to be humored when necessary and evaded if possible, while the paint or varnish manufacturer who promulgates such propositions is a dangerous crank, about as useful to society as an anarchist. "That," said the manager of one of the great bridge companies, "is a good paint, but it always makes me laugh when I see a barrel of it; observe the notice on the barrel-head: 'Do not thin this with anything.' Well, we thin it just the same. Oh, we have to thin it a little, you know, or we couldn't put on two coats; with the same brush, you know; one coat going this way"—with a sweep of the arm indicating a free and powerful artistic treatment—"and the other"—with a return sweep—"going this way. Why," plaintively, "do you suppose we wish this steel to last forever?" "I suppose," said I sadly, "you consider me an enemy of the human race." "Oh, no, you're a good fellow, but you are an enemy of the steel men."

Apply Paint to a Clean Surface.—The most important condition affecting the adhesion of any coating to any metal is that it should be applied to a clean metallic surface. If the surface is covered with dirt or grease, the coating does not come in contact with the metal and so does not adhere to it; and if the dirt comes off, the coating comes with it. It might be supposed that grease would be absorbed by the paint or varnish, but the coating of grease or oil does not very readily mix with these. If it were desired to mix such things, it would ordinarily be thought necessary to agitate them thoroughly together. But an important consideration is that the grease is always mixed with and covered by an adherent film of dirt which interferes with the action of the paint or varnish upon it, which consequently makes a film on a loose, greasy foundation. Further, the oil or grease is usually a mineral oil, sometimes mixed with rosin or rosin-oil, and if mixed with the regular coating will destroy the characteristic and valuable qualities of the latter. Iron and steel beams and the like should not be laid on the ground, but on skids or trestles. They are heavy and press into the earth, which adheres to them; in wet weather they become covered with mud, which the contractor strenuously objects to removing before painting. "Do you expect me to clean this iron with a tooth-brush?" was the angry protest of the manager and one of the principal stockholders of one of the largest construction companies in New York, when the engineer was urging him to wash the mud off the beams which had been lying in the street, although his contract specified much more thorough cleaning than he was asked to do. Sometime when steel becomes more costly than it is now, or opinion on these matters becomes more enlightened, it will be kept under shelter until the time comes for its erection.

Mill-scale.—But oil and dirt are not the only things found on steel. All structural metal as it comes from the mill is covered with mill-scale, which is the black oxide of iron resulting from the action of air on the hot metal. Frequently this scale is in several layers; sometimes these stick together rather firmly, sometimes the outer layers separate readily from those beneath. Steel plates are often coated with a thin blue or iridescent mill-scale, which immediately overlays the unoxidized metal, to which it sometimes adheres with great tenacity. This is the anhydrous sesquioxide, and is exactly similar in appearance and composition to the beautiful iridescent specimens of hematite ore which may be seen in any mineralogical collection. This is an extremely refractory substance, insoluble in acid, and might be thought to be a sufficient protective coating in itself, but it is hard and not very elastic, and its rate of expansion differs from that of the metal, so that it soon becomes a network of cracks, which allow water to reach the underlying metal, which then rusts and the rust creeps under the little patches of scale and they are thrown off. This may be easily seen by immersing a piece of such iron in acid, which can reach the metal only through the cracks in the scale. Scale which is of a more pulverulent character offers little or no resistance to atmospheric agencies, but it does not scale off easily unless in deep layers. It is dangerous to leave such oxide in contact with the iron, for it absorbs and holds in contact with the metal the moisture and acids in the air and in various ways acts to induce further and deeper oxidation. It might be thought that saturating the oxide with oil would prevent any further change, but this idea, though it crops up from time to time and is the base of many a humbug in the paint line, is not in the least supported by practical experience. I do not mean to say that a surface covered with mill-scale, or even with ordinary rust, may not be benefited by a good paint or varnish. These coatings will undoubtedly retard the further action of rust, but do not prevent it. More than a hundred years ago, Smeaton, one of the greatest engineers of his time, said he "had observed that when iron once gets rust, so as to form a scale, whatever coat of paint or varnish is put on over this, the rust will go on progressively under the paint." The following century of observation has made no change in this remark, which is only confirmed by longer experience.

Rust must be Removed.—Iron and steel are of a grayish-white color. When it is desired to coat articles of this metal with porcelain or a vitreous enamel the workman finds it absolutely necessary to have the surface show this color of the pure metal in all its parts, for if there is any scale or rust on the surface, even in minute spots, the enamel will chip off at those places. This clean surface he gets by clearing off the scale with acid, in a manner to be described later, or by the use of the sand-blast, or sometimes by scraping and polishing the metal. At all events, the enamel is applied to the metal and never to an intermediate coating. The electroplater, who deposits another metal, such as copper or nickel, on iron, is equally thorough. The bicycle-maker, who covers his frames with a japan enamel, cleans them in the most perfect manner on an emery-belt, after which they must not be touched even with the finger until the enamel is applied. In making tin-plate, the iron plates are cleaned by acid and go direct from the acid-bath to the pot of melted tin, for otherwise no adhesion will take place. Galvanizing, or plating with zinc, is done in the same way.

No Coating will Stand over Oxide.—Excepting the painter, every one who applies protective coatings to iron or steel insists, as a matter which will not admit of discussion, on the absolute and fundamental necessity of removing not merely all loose scale and dirt, but absolutely all scale and all oxide, so as to apply the coating to the pure metallic surface. Otherwise it has been found that, sooner or later, the oxide will separate from the metal surface and of course the superimposed coating has to come off. This is what I mean when I say the conditions which favorably influence the adhesion of other coatings are desirable for the application of varnish and paint, and it is this idea of having an absolutely clean metal surface on which to apply these coatings which seems the extravagant dream of a doctrinaire to the ordinary contractor, who will tell you that paint forms a continuous film and keeps out the air and water, so that there can be nothing to cause the closely adherent oxide to separate from the metal. It is a sufficiently complete answer to this argument to repeat that universal experience shows that nothing can prevent it in practice. If it cannot be done with such a perfect coating as electroplate or a vitreous enamel, nor with a coating which in some respects is even more remarkable, namely, one of baking-japan, which more nearly resembles a varnish or paint, it is idle to expect it with these latter, which are in their nature somewhat porous and with which we have to obtain protection by putting one coat on over another, trusting to the successive coats to fill up the pores and imperfections of those beneath. There is no doubt in my mind that the right way to prepare a steel or iron surface for painting is to clean it so that the gray color of the metallic iron will be everywhere seen. This may be done in some cases by scraping, in some by pickling in acid, in others by the sand-blast, but in all the cost will be considerably more than is now common, because more work is done and a better result achieved. Money judiciously spent to get a good surface is wisely invested; no one doubts that it is if really high-class work is in question. No doubt there is a great deal of work of a more or less temporary nature where the cost of such high-class treatment is not justified, but there is no place where a protective coating is called for where it is not worth while to make some effort to secure a fairly good surface, free from mud and dirt and loose scale, for the varnish or paint. We may also consider the practice of the painter who works on wood. No one ever thinks of painting on wet wood; the paint will not stick; if it does not immediately come off, it will subsequently blister; and even in such rough work as exterior house-painting the painter removes all loose dirt, old paint, etc., by scraping and brushing, as a preliminary; in fine work, such as repainting a carriage, the old paint is removed by scraping or burning off, and the surface made clean and smooth and properly prepared by special fillers, so that the paint or varnish may go on in a coat of uniform thickness to a surface for which it has a natural affinity. Thus it will be seen in all other painting the proper condition of the surface is a subject of practical consideration, and its preparation a matter of serious care. This also indicates that like precautions should be taken with steel, in fact greater, because steel is in most situations more perishable than wood.

Why Steel is not Fairly Treated.—The curious reader will perhaps wonder why it is that difficulty should be found in having steel properly cleaned and painted. Primarily the trouble is with the engineers who design and direct the work. If they, as a class, felt the importance of the matter and were always as strenuous about it as they are about the mechanical details, and made it a rule to include in their estimates a reasonable amount for having such work properly done, there would then exist a better general practice, and if the average were higher it would be comparatively easy to get really high-class work done. Structural steelwork goes mainly into two classes, bridges and the framework of buildings. The building with a steel framework is primarily designed by an architect who, while not without engineering knowledge, hands over the details of construction to an engineer. The chief architect himself is mainly concerned with the design of a building suitable in its general and detailed arrangements for the purposes of the owner and in having its artistic features and its ornamental details as agreeable as possible, and strict regard must and should be had for economy of construction. Usually a sum to be expended is fixed upon at first, and the common experience is that for various reasons the estimated cost is finally exceeded. The architect usually does not know or claim to know much about protective painting. The engineer is sometimes directly and sometimes indirectly in his employ and receives his directions. He is, therefore, not finally responsible and, not being oversupplied with subordinates, does not feel like assuming unusual authority or cares. The metal framework is to be eventually covered from sight, and as it is inclosed it is not as likely to rust as though exposed; and above all, the current practice of architectural engineers is to be indifferent about painting, so that, with lack of responsibility, lack of authority, disbelief in the vital importance of the subject and accordance with current practice, the engineer leaves the painting largely to the contractor, and it is unreasonable to expect the latter to spend money for material or labor which are not called for. Further, it is commonly the case that when the money to build with is ready it is important to get the building done as soon as possible. So the steel is rushed through the shops as rapidly as may be; when it is delivered it is in the street in front of the building, and the building permit is limited; hence it cannot stay there, but must be put in place at once, and then the masons are waiting and there is no time to paint.

Stone does not Rust.—The engineer consoles himself by thinking that he has done the best he can and as well as other people do; and in fact the engineer who holds that life is too short to be studying this paint question and that there is no opportunity in the construction and erection of metal-work for its proper application may feel confident that he has good company and plenty of it; but his attention may be called to the fact that some of our best and most important railroads have gone back to the construction of enormously expensive stone bridges simply because stone is reliable, while steel, as now treated, is not.

As to bridge construction, it is common practice for one department, whether of a private or public corporation, to design and erect a bridge, and then turn it over to another department for maintenance, and the bridge engineer holds that painting is a part of maintenance, and that he may build the bridge without regard to paint and let the engineer of maintenance paint it as often as he likes. Hence it is of no use to try to interest such a bridge engineer in materials or methods of painting. A little consideration will show that this position is untenable if, as has been claimed, paint is engineering material. The constructing engineer might as well say that, as defective rivets and bolts have to be renewed by the department of maintenance, it is of no importance to him what is the quality of material or workmanship employed in riveting. The place to begin painting is on the metal, and the first coat is of more importance than any subsequent one. My own belief is that a bridge should never, except for decorative effect, be repainted throughout; it should be well and properly painted when built, and any spots which are defective should be repainted from time to time, precisely as all other repairs are managed; no one would think of conducting other repairs in any other way, and the paint is just as much a part of the bridge as any other material and should be treated in the same way; and I am glad to be able to say that some of the best-maintained railways have adopted this practice.

Scraping.—This doctrine that rust and scale should be removed as much as possible before painting is, of course, no new thing; and the earliest method, and one which will always be in many cases the only one available, was to clean the surface by scraping. The most common scraper is one made by grinding the end of a large mill-file, which makes an efficient tool. But there are many places which cannot be reached with such an instrument, and now the workman is provided with sets of scrapers of different widths, and with a hammer and chisel, which are sometimes necessary. The common straight scraper is operated by pushing, but others are made with the scraping end bent at a right angle to the shank, which are pulled, like a hoe, toward the operator. These are also made in different widths. The edge of a scraper is naturally straight like that of a chisel, but the workman is also sometimes provided with one or two wide ones having the edge serrated, like the teeth of a saw or of a serrated ice-chisel, and these are useful for breaking up scale so that it may more easily be removed.

Wire-brushing.—After the scraping it is customary to go over the surface with a wire brush, which leaves a good surface, but the brush alone is not an efficient instrument. In my own laboratory there is a rotary wire brush driven by power with a peripheral speed of about five thousand feet per minute. A suitable table is arranged so that the piece of metal to be cleaned may be mechanically held at the right place and the brushing may be continued as long as the operator desires. This is probably the most favorable condition for the use of a wire brush, but it is found that even here it is impossible to remove scale which adheres closely or which is very thick. I conclude, then, that the wire brush is not sufficient and that its use should be preceded by scraping. The painter's torch is sometimes used as an accessory. This throws a jet of flame on the surface of the metal, and as the rust and scale become much more heated than the metal they tend to crack off and are more easily removed, and any water which is held in their interstices is driven off, but of course the hydrated oxide is not dehydrated in the chemical sense, for it requires a much higher heat to do this, as has been already explained. Bridges which have been erected can usually be cleaned only in such ways as have been just described, although on some railroads bridges in place, especially old ones, are cleaned, usually in part only, by the sand-blast. Those parts of the bridge which are most badly rusted are cleaned with the sand-blast, and the rest of the bridge with scrapers and wire brushes, on the theory that the most exposed parts need the most care and that the less rusted members will last long enough with more inexpensive treatment, which is doubtless correct.

Sand-blast.—The most thorough and perfect manner of cleaning metal in any mechanical way is by the sand-blast, which is a stream of particles of sand thrown with great velocity against the surface; the grains of sand have sharp cutting edges and partly by cutting and partly by the impact or hammering of these little pieces of quartz the scale and rust are cut and broken up and removed. It has been proposed to throw the sand with levers, as from a catapult, or by centrifugal force, but the only practical way is to mix it with an escaping current of compressed air, which carries it along with great velocity, hence the name. This method of applying power for cutting and abrasion was invented by Gen. Benj. C. Tilghman, of Philadelphia, and was patented by him Oct. 18, 1870, the patent being numbered 108,408.

Among the most important claims granted by that patent were the following:

1. The cutting, boring, dressing, engraving, and pulverizing of stone, metal, glass, pottery, wood, and other hard or solid substances by sand used as a projectile, when the requisite velocity has been imparted to it by any suitable means.

2. The artificial combination of a jet or current of steam, air, water, or other suitable gaseous or liquid medium, with a stream of sand, as a means of giving velocity to the sand when the same is used as a projectile as a means of cutting, boring, dressing, etc., etc.

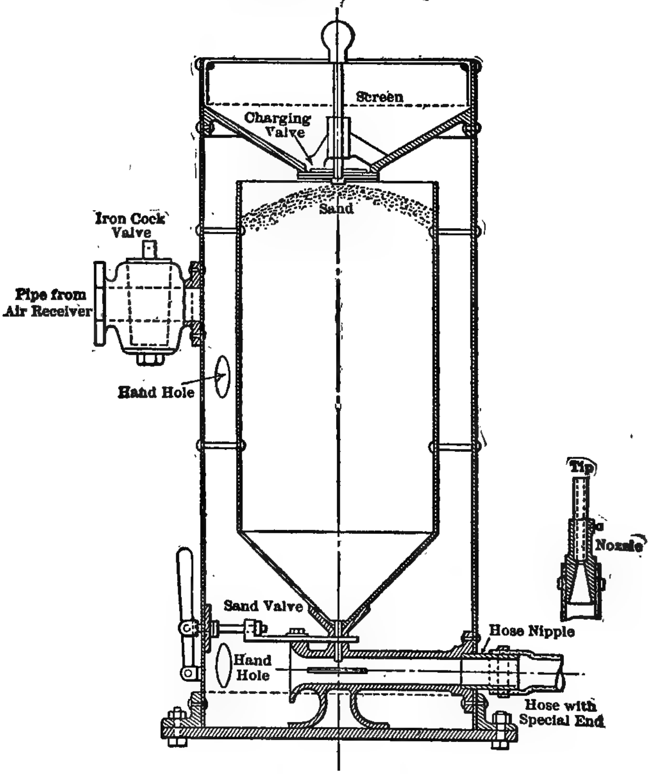
7. When a jet or current of steam, air, water, or any other suitable gaseous or liquid medium is employed to give velocity to sand used as a projectile, as a means of cutting, boring, dressing, etc., the use of the following devices for introducing the sand into the jet of steam, air, water, etc. First, the suction produced by the jet of steam, air, water, etc. Second, a strong, close vessel,

or sand-box, into which the pressure of the steam, air, water, etc., is introduced and through which, when desired, a current of it may be made to pass.

It is obvious from the foregoing that there is no existing patent on the process, and while there is some patented apparatus which is preferred by some of the people who use the process, this is equally true of a very large proportion of all machinery in use.

The Tilghman apparatus as improved and patented by Mathewson is shown in section in the following illustration.

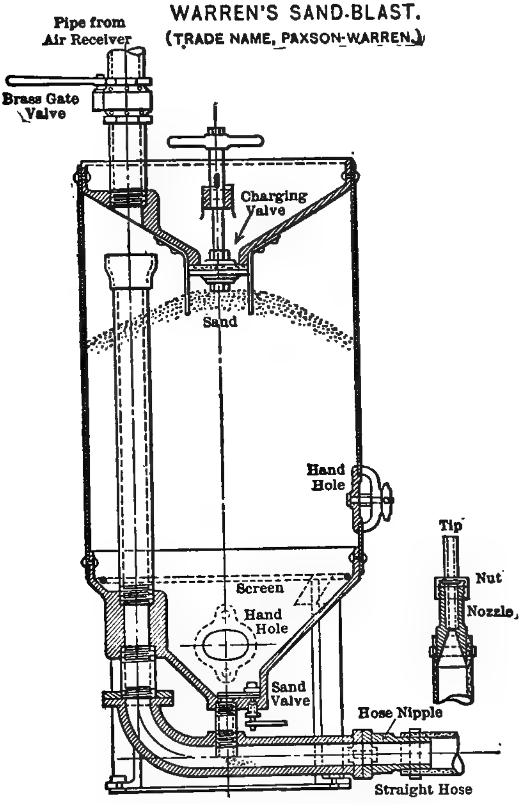
MATHEWSON'S SAND-BLAST.
(TRADE NAME, TILGHMAN.)



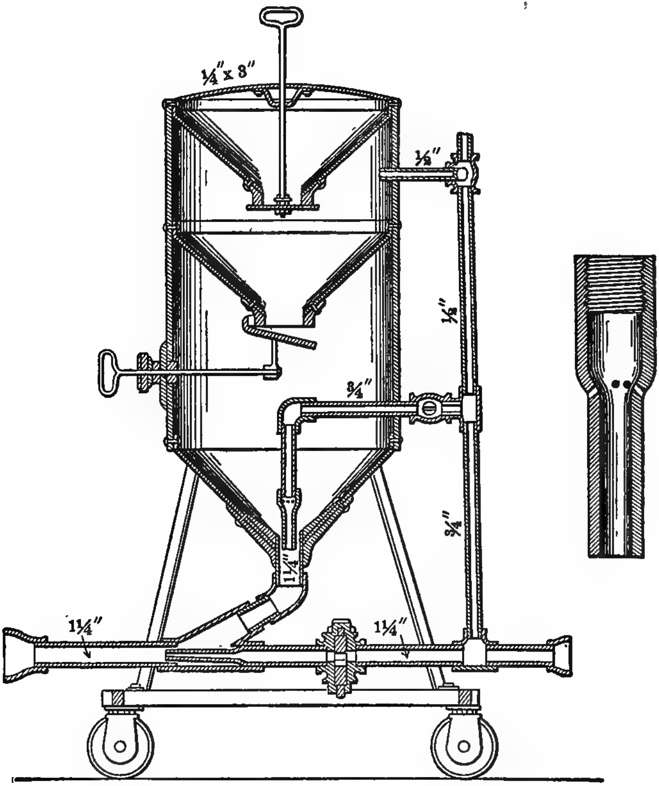
In this apparatus a slotted slide, operated by a lever, regulates the quantity of sand introduced into the current of air. This machine was patented Dec. 25, 1894; No. 531,379.

In the Paxson-Warren machine, shown in the next figure, the feed of the sand is regulated by a revolving piece, or valve, which covers the opening in the bottom of the hopper to the extent desired to let the proper quantity of sand fall through it and into the air-pipe.

WARREN'S SAND-BLAST.
(TRADE NAME, PAXSON-WARREN.)



In the machine patented by J. M. Newhouse of Columbus, Ohio, shown in the illustration on the next page, the sand passes from the hopper at the bottom through an annular opening around the end of a nozzle-shaped steel piece, which decreases in its outer circumference toward the end and, by raising or lowering it, this annular opening may be increased or diminished in size. The distinguishing feature of this appliance is the use of this nozzle as a siphon with its perforation as shown. The small holes permit part of the air which flows through the small pipe and the siphon to escape outwardly through the surrounding sand, thus stirring it up and preventing it from clogging the opening. A similar siphon, without the perforations, is placed in the air-pipe.



THE NEWHOUSE SAND-BLAST.

The process of cleaning with the sand-blast is essentially as follows: Air at a pressure of 20 to 25 lbs. per sq. in. is furnished by any suitable air-compressor. If we assume that we will use a discharging-nozzle $\frac{9}{16}$ in. internal diameter, when new, each such nozzle will require 120 cu. ft. of air per minute, measured at atmospheric pressure compressed to show a pressure of 15 lbs. per sq. in. at the nozzle. This is, however, to be regarded as a minimum, for it is advisable to use a somewhat higher pressure, say 20 lbs., and the nozzle rapidly wears away until it reaches a diameter of $\frac{3}{4}$ in., at which it will discharge nearly twice as much as when new, so that in practice it is well to provide an air-compressor handling 240 cu. ft. of air per minute and compressing the same to 20 lbs. per sq. in. Recent work has shown that a pressure as high as 35 lbs. per sq. in. is desirable and economical for removing heavy scale, which a blast at a lower pressure will not remove.

Into this current of air dry sand is introduced at the rate of about 10 cu. ft. of sand per hour for each such nozzle, or 1 cu. ft. of sand to 1000 cu. ft. of air. The sand must be artificially dried; some operators use coarsely powdered quartz. This latter can be used five times in succession; and in general the sand may be used until it is broken up into a powder too fine for use. In the plants which the writer has inspected the sand and air are carried to the nozzle through a heavy rubber hose about 2½ in. diameter. This is not worn away by the current as a metal pipe would be, but it is necessary that the air should not be hot, as this would rapidly injure the hose. The nozzles are short pieces of extra-heavy iron pipe and have to be renewed at frequent intervals. From data furnished me by Naval Constructor Bowles I find that the cost of cleaning the bottom of a ship in dry dock amounted to about 4 cents per square foot, but this was done with an experimental plant, and the method of drying the sand, which was used only once, was costly, and the cost would certainly have been reduced to 3 cents per square foot if a permanent plant had been in use. Since the installation of a permanent plant no work has been done of sufficient magnitude to give figures. This was an exceedingly rusty surface, but with this same experimental plant the mill-scale was removed from 3,155 sq. ft. of surface of steel plates at a cost of $17.60, or about ½ cent per square foot and at the rate of 4¾ sq. ft. per minute per nozzle.

It may be well to add that in all the work referred to, which was practically field work, being carried on out of doors and with a somewhat portable plant, the labor amounted to one man to hold each nozzle, one man to attend to each two sand-boxes, and one man to clean up and carry sand for each four nozzles. The supply of compressed air is an expense of a different sort, as is also in field work the matter of staging, etc., but all are included in the prices given. It seems reasonable to suppose that where many pieces of metal of the same general character are to be treated in a shop fitted up for the purpose, contrivances may be introduced which will do away with a considerable part of the labor.

Pickling.—Iron and steel may also be cleaned by pickling in acid and the subsequent removal of the latter. This may be done in the following manner: The pieces of metal which have been made ready for assembling are immersed in hot dilute sulphuric acid having a strength of 25 to 28 per cent. Some use acid of 20 per cent. It is kept in this until the whole surface is free from rust and scale. This will take from six to twelve minutes. If the pieces of metal are somewhat rusty, so that rust has started underneath the scale, the shorter time will be found sufficient, but if it consists of plates covered with closely adherent blue or iridescent rolled scale, the longer time will be necessary, since this scale is itself insoluble in acid and is removed by the latter penetrating the innumerable minute cracks in the scale and attacking the iron underneath, thus mechanically throwing off the scale. If, on the other hand, the iron is uniformly rusty, this coating of hydrated oxide readily dissolves in acid, and in fact a weaker acid of 10 to 12 per cent. might be used, although the stronger acid is quite safe but will require a shorter time. It has been suggested that it is desirable to previously clean the metal with caustic alkali from all grease, etc., but if acid of the above strength is used and kept as hot as possible this will not be necessary. As soon as the acid has reached the iron in all parts of the surface, the metal is taken out and washed by jets of water discharged against it under high pressure, not less than 100 lbs. per square inch and much better if double that. In this way the acid may be thoroughly removed.

In Germany it is said to be customary to use acid of 9 or 10 per cent. cold, and the metal is left in it five hours. This makes a much larger plant necessary and has no advantages.

If it is attempted to remove the acid by soaking the metal in still water, the following difficulty is encountered: the iron becomes immediately coated with a gummy or colloidal substance, very difficult to remove. What this is, is not known to the writer, but is it well known that there are a number of insoluble or difficultly soluble compounds of iron with sulphuric acid, and it is probable that some of these are precipitated on the surface of the iron when water removes the excess of acid, but if a jet of water is used the mechanical effect is to remove the adherent ferrous sulphate at the same instant, leaving a clean metallic surface. It is also possible that if the acid contains arsenic, as is the case with much of the acid made from pyrites, this may also be precipitated on the surface. In fact, it is sure to be, and acid free from arsenic should always be used for this purpose, and as a matter of practice it is insisted on by many.

It is often difficult, and sometimes impracticable, to pickle steel high in carbon and cast iron containing graphitic carbon, on account of the deposit of a film of carbon like stove-blacking on the surface. Muriatic (chlorhydric) acid has been used instead of sulphuric, but it is not well suited for the purpose, being much more expensive and difficult to remove. It also forms a gummy coating on the iron, worse than that with sulphuric, and in the subsequent alkaline treatment it must be removed by caustic soda instead of lime, or sometimes by a solution of sulphate of zinc.

After the iron has been freed from sulphuric acid in the manner just described, it is put in a bath of lime-water or milk of lime, boiling hot (it is very important that it should be hot), and left there long enough to reach the temperature of the liquid. It is then removed to an oven and dried, after which the lime is brushed off. If desired, the lime may be removed by washing before putting in the oven. In this case it will be found that the surface, which is perfectly clean and bright, rusts very easily and quickly, whereas if the lime is removed by drying and brushing, the surface is much less likely to rust, although even then it rusts easily and should be painted immediately.

For most of the foregoing information relating to pickling I am indebted to Mr. E. G. Spilsbury, who has had extensive experience in this work both in Europe and the United States, and has applied the process to structural steel (bridge) work, as well as to wire and wire rods.

Some of the largest work recently done has been treated as follows: The steel as it came from the mill was put in hot 10 per cent. caustic soda solution until all the grease and oil came off; with this came all the dirt, with which the shop grease had become mixed, and an appreciable amount of scale, making altogether a bulky sludge. Next the steel was washed with boiling water; then it was put in hot 10 per cent. sulphuric acid until the metal surface was everywhere exposed; after which it was dipped in boiling water, then in hot 10 per cent. solution of carbonate of soda, then well washed in hot water, and finally dried in an oven. The results were all that could be desired.

Much detailed information concerning the use of the sand blast in cleaning structural steel may be found in the paper on the subject by Mr. George W. Lilly, in the Transactions of the American Society of Civil Engineers in 1903 and in the ensuing discussion.

Treatment at the Mill.—Many engineers believe that the time to begin the protection of steel is at the rolling-mill, before the metal is cold. It is said that careful methods of rolling will prevent the formation of thick scale and that most of the scale may be removed as the metal comes from the rolls, immediately after which the hot surface (at a black heat) is to be sprayed with oil or varnish or paint and the heat remaining in the metal will be enough to bake this before the metal becomes entirely cold, thus producing a coated and protected surface, which insures freedom from rust for a period of at least some weeks, during which the metal may be built up into riveted members and made ready for painting. The details of this plan have not at present been worked out in practice, but there is no doubt in my mind that it is a very desirable thing and I believe it to be practicable. Putting bars of various sections through straightening rolls has been proposed as a means of removing the scale. It will remove thick scale and will loosen all but the most closely adherent thin scale. This may be seen where sheets of steel are rolled in a boiler-shop or in making large pipe. Coatings have been very successfully applied to such surfaces.

Shop-painting.—In bridge work and the like, if it is decided to clean by pickling or sand-blasting, it is a question as to when this should be done. If it is done when the metal comes from the mill (supposing that it has not been coated hot in the way just mentioned) it will be necessary to do something to it at once to prevent its rusting; for pickled or sand-blasted iron will begin to rust almost immediately and the iron has to be at least a week in the shop before it can be painted after assembling. What can be done to it? Probably a coat of linseed-oil will be applied. Paint will be objected to by the shopmen and the inspectors will demand a transparent coating. Boiled oil is commonly used for any such purpose because it dries rapidly, but it is less durable than raw oil, and it is the common opinion of the manufacturers of mixed paints, whose opinions in this matter are entitled to great weight, that boiled oil is less durable than raw oil to which enough drier has been added to make its drying qualities equal to boiled oil. The drier should probably be one made at low temperatures. The cleaned surface may then receive a coat of such oil and allowed a day or two to dry. But it must be observed that oil does not dry to a hard film, but is soft and rather sticky, and probably a very elastic varnish would be better because cleaner; less likely to be contaminated with dirt and machine-oil in the shop. Probably the increased cost will be a barrier to its use. It might, and I think should, be very thin, as it would then be harder, and it is not depended on for permanent protection, but it should be of good quality as the foundation for all subsequent painting.

A much better plan is to defer the pickling or sand-blasting until the structural steel has been long enough in the shop to have been cut to required dimensions and all the holes punched or bored and otherwise made ready for assembling. Then let it be removed from the shop to the building where the sand-blasting is done (for it should be under shelter), cleaned, and painted. It is practicable to have it painted at this stage unless, for purpose of inspection, it is thought better to have it oiled; or, better, varnished. When the painting or varnishing has been done and two or three days for the coating to begin to dry have elapsed, it may be carried back to the shops and riveted up into members, care being taken to again paint, and thoroughly, all surfaces which will hereafter be inaccessible, for rusting in riveted joints not only weakens but impairs the rigidity of the structure. It is only fair to say that I have been told by engineers of bridges who have had much experience in taking down riveted work that it is uncommon for riveted joints to be dangerously rusted and that the webs, rods, and other extended parts rust off before the joints give way. This is partly because there is more metal at the joints than elsewhere and probably partly because care is usually taken to paint these surfaces heavily, and the paint is mechanically protected by the location from external injury.

Shop-marks.—Where it is undesirable to paint portions of the surface on account of shop-marks, care should be taken that these marks are as compact and small as is reasonable and to see that they receive an extra coat in the final painting. Planed and turned surfaces are at this time coated with a non-drying grease, commonly a mixture of white lead and tallow, or a mineral grease similar to vaseline, which many prefer.

Crevices.—There are also found many crevices which will be inaccessible after erection, and it is customary to fill these with a fresh mixture of neat Portland cement and water. It is possible to use other cementing substances, but nothing is so easily used as the above, and it is good enough.

Shipping.—The work is now ready for shipment. In shipping, care should be taken to avoid scraping off the paint and to avoid nesting the pieces except with packing material between them; and, as has been already said, the pieces should not be laid on the ground, but on skids or trestles. The paint should be reasonably dry before the shipment is begun, not thoroughly dry, but it should have its initial set and dry enough to be safely handled, usually in two or three days after the paint has been applied, sometimes one day in hot weather.

Striping Coat.—The materials may now be supposed ready for erection, after which the work should be carefully inspected, and if there are any rusty spots these should be thoroughly cleaned and painted, and any places where the paint has been rubbed off should be repainted, and at this time all exposed edges and angles should receive an extra striping coat of the protective coating, covering the edge and the adjacent surface one or two inches from the edge on each side, and all nuts, bolt-heads, and rivet-heads should receive an extra coat. This may be called the striping coat and is necessary for the following reasons:

When paint begins to dry there is at first a sort of skin formed on the surface, which contracts, and on rounded surfaces like rivet-heads and on angles and edges seems to press away the liquid paint beneath, so that on such surfaces there is less than the normal amount. The same tendency to contract also exists on flat surfaces, but in this case it is a balanced tension and produces no effect. There is besides the action of the painter's brush, which presses harder on such places and draws off the paint; but that this is not the main cause is shown by the fact that pipe sections and other things which have been coated by dipping exhibit the same appearance. In making paint tests, it is necessary to leave out of account a strip about an inch wide along the edges of the plate unless that portion has received an extra coat, and the fact is well known to inspectors that such surfaces are always thinly coated. The extra striping coat is therefore necessary if we are to have two full coats or their equivalent over the whole surface, and it is the more important because these portions are more exposed than the flat surfaces.

When this striping coat has become dry (two weeks or longer if possible after its application), another full coat of the protective coating should be applied to the whole surface. Of course, if a coat of oil or thin varnish has been applied in the shop instead of the regular protective coating, another full coat of the latter will be necessary after erection, and the striping coat may intervene between these two full coats. If, during erection, any small cavities are produced they should be filled as already described, and any large ones should be drained by making suitable openings. Care should be taken that no undrained places are left which may fill with rain or ice; the latter by its mechanical action is likely to tear off the best paint.

If the preceding directions have been followed, the structure has two full coats of a protective coating and is ready for decorative painting, if any is desired. If not, it should have a third coat of the protective coating. Two or three or even six months may, however, be allowed to elapse before this final painting is done. The structure may now be regarded as finished and turned over to the maintenance department, who should watch it carefully and repaint it before it begins to rust, or, at least (perhaps better), touch up any doubtful places and so avoid any general repainting. I believe that a structure treated in this way would be easily maintained in practically perfect condition at a cost so low as to be unimportant. It should not be forgotten in connection with this whole subject that paint should not be applied in freezing, rainy, or misty weather, or to surfaces which are not dry and clean, but this is true of all painting. It is sometimes necessary to apply paint in cool weather. It is then allowable to heat the paint to a temperature of 150° F., which will be found much better than thinning it.

It is folly to expect any general agreement as to what is the composition of the best coating for structural metal. Those which are practically in use are:

1. A variety of mixtures, of which coal-tar dissolved in benzole or dead-oil may be taken as the type.
2. Paints made with linseed-oil or an alleged substitute, and pigment; containing some drier and usually some varnish.
3. Varnishes.
4. Varnish and pigment paints (the so-called varnish enamels).

Other materials are used on water-pipes, but these will receive separate discussion.

Coatings of the first class need very little discussion. They are used because they are cheap. I have heard of a mixture of asphalt and mineral oil which cost, exclusive of packages, only seven cents per gallon, which was used on some railway bridges; the labor of applying it, and the constant repainting which was required, made the final cost of maintenance so great that the authorities changed to the use of a paint costing a dollar and a half a gallon. Most of the so-called asphaltum varnishes used on metal-work come under this heading. They contain frequently nothing more expensive than coal-tar or petroleum residues, and are thinned frequently with kerosene. Rarely these mixtures are made with asphaltum and softened with palm-oil stearine, or something of that sort, and thinned with benzine; such a mixture may be very good for temporary use, being impervious as long as its elasticity remains, and, unlike much coal-tar, being free from acid which will attack the iron. Some of the cheap coal-tar mixtures are actively corrosive; some are mixed with pulverized lime to remove the acidity. It is by no means unusual for a contractor, especially on public work or on work where the inspection is not good, to contract for the use of a good paint, and use instead some of these excessively cheap and worthless mixtures. I would not include adulterated paints under this heading, but among those paints which they imitate; and I do not say that some of these mixtures or compounds are not good enough for temporary use; and not a little steel is used in this way. But in general, it may be fairly said that these mixtures are not as economical as better paints, and hence are not suited for general use.

Oil Paints.—In the second class, that of oil paints, are found the most commercially important of the preservative coatings. It will appear before this essay is finished that the author believes in the use of varnish paints as the best, but it must be observed that linseed-oil is the elastic base of varnish, and as the varnish-resins are more costly than oil, and as any labor expended in making varnish increases the cost of the materials contained in it, so it is that a straight linseed-oil paint may be made at a lower price than a varnish paint and is the best paint that can be had at the price. When we are able to say that such a paint is really a good paint and that it is the best to be had at the price, we have given reasons for its use which no possible arguments can overthrow, though they may modify their application.

An oil paint is composed of a pigment mixed with a liquid or vehicle, which consists usually of raw linseed-oil to which has been added 5 to 10 per cent. by volume of liquid drier, this latter containing usually both lead and manganese, and either turpentine or benzine as the volatile part. This mixture of oil and drier is not very likely to change if kept from the air and is chemically unaffected by most pigments; hence an oil paint has excellent keeping qualities. Of course the pigment will in time settle to the bottom, but commonly it can be stirred up again; however, a paint should always be used up before it is injured in this way. Containing little volatile matter it does not evaporate, and the oil works freely under the brush, more so than the best varnish, so that an oil paint is the easiest to apply of all paints. This in itself is a great advantage, for it is easier both physically and mentally to put on a good-looking coat of oil paint than of any other. This quality of working freely and sweetly under the brush is the best thing about an oil paint, and this alone is the reason why these have displaced the varnish paints in the work of modern artists, while probably all the so-called oil paintings of the great painters of the middle ages were done in oleo-resinous varnish. Oil is, when spread in a thin film, very slow to set, and when it finally begins to set it goes on rapidly until the paint is hard enough to handle; the thorough hardening takes a long time, perhaps a year. This slowness of setting facilitates working with a brush and, especially on wood, gives it time to penetrate the pores of the surface to which it is applied. A coat of oil is, therefore, often used on wood as a priming coat even where varnish is subsequently to be used. On account of its remarkable fluidity linseed-oil may be mixed with a large proportion of pigment, and if this pigment is very cheap it may actually reduce the cost, and if it is dear the oil-paint still usually has advantages in price because of the lower price of oil than of varnish, and, as it carries more pigment, its covering power, or opacity, is greater. Anything which enables two coats to take the place of three is a great advantage, for the cost of labor is an important item, sometimes being much more than that of the paint. Oil is usually, when fresh, more nearly colorless than varnish, and on that account displays well the color of the pigment. This advantage, however, disappears very shortly, for oil paints quickly become dull and show the effect of the weather more than varnish paints.

The possible supply of linseed-oil is unlimited. Flax will grow anywhere that any cereals will, and when the seed is high in value the acreage quickly increases, so the oil is subject to large and rapid fluctuations in price. When it is high, there is a strong temptation to adulterate it or to substitute something for it.

Oil Substitutes and Adulterants.—The most common adulteration is with mineral oil, but substitutes are from time to time proposed, the most important probably being fish-oil. This is normally a non-drying oil, but it may be cooked with lead and manganese and made into a slowly drying oil.

This fish-oil "boiled" with driers is said by some very good authorities to be a good addition to the extent at least of 20 per cent. to linseed-oil for making roof paints, its slower drying not being noticeable in this case, and an advantage of greater elasticity is claimed. This may be so. I have no experience in the matter, but I think this is believed by some very honest and very well-informed makers.

Most of the so-called substitutes are various mixtures of mineral oil, fish-oil, rosin, rosin-oil, and rosin varnish. They are mainly sold to be used surreptitiously as adulterations or substitutes for linseed-oil, but from time to time are put out boldly with a flourish of trumpets as a new and improved variety of paint oil, are sold for a time to the unwary, and then are forgotten. There is no oil worthy to be compared with linseed-oil for paint.

As has been stated in the chapter on driers, the objection to these preparations is the danger that they may continue to act after the film has become properly oxidized. But a paint which dries slowly makes a rather soft film and is without lustre, so it is common to add to it a quantity of varnish, which hardens the film and makes it smooth and shining. If this varnish is made of good materials it improves the paint in every way except working quality and covering power and, in the amount generally used, does not sensibly injure it in these respects. Such a varnish ought not, however, to be made of rosin, but of some of the true varnish-resins, and it will, in the nature of things, add to the cost of the paint. A cheap rosin varnish is often, I fear I might say commonly, used for this purpose, and is bought by the paint-maker at less than the price of oil, sometimes at half the price of oil. The worse it is the greater is the temptation to use it to excess; in fact, any varnish of this sort is an excess.

Chemical Action.—It is generally assumed that there is no chemical action between oil and pigments, but this is not certain. There can be little doubt but that pigments influence the drying of oil in some way, and that the oil in a paint film differs from the dried oil of a film containing oil alone. This may be a physical action, but it may be in some cases at least partly chemical. The effect is often quite marked, and is important in determining the durability of the coating. Little careful chemical study has been made on this difficult subject; a considerable part of what has been written has been with a desire to market certain classes of paints, and is contrary to general experience.

As to the exact mechanism of how a paint or varnish film protects metal from corrosion we know little. We do know that rust is chiefly hydrated iron oxide, and that it is most commonly caused by the exposure to moist air and that carbonic acid is active in promoting its formation; carbonic acid is always present in the air, but where it is present in unusually large quantity rusting goes on rapidly. Moisture is also always in the atmosphere; so that access to air will cause rust. But in cold and relatively dry air, as in deserts in cold countries, its formation is slow; in wet and warm regions it is rapid. Other things also occasion it; sulphurous gases, which are acid, or any other acids, act strongly; but these are present only in cities and places where coal is largely consumed.

It has been observed that iron does not rust in pure distilled water. This is not a matter of the slightest practical importance, because iron is never exposed to pure water and nothing else; but it is interesting from a theoretical point of view. The fact has been disputed; and rusting has been observed in distilled water. The opposing parties have then shown that the water thus used contained carbonic acid; and the matter was experimented on and disputed about for several years. The victory seems to have rested with those who hold that pure water does not rust iron; but as aforesaid, this is not very important, because all air contains water vapor and carbonic acid, and when it gets to the iron rusting takes place.

Attempts have been made to show that some pigments tend to cause rusting and others the contrary; and pigments have been grouped as accelerators and inhibitors of corrosion. This grouping was based on the behavior of mixtures of the pigments with water, in which mixtures pieces of iron or steel were placed. This was not a proper experiment to make for the purpose, because water and air form an oxidizing mixture, while linseed-oil, which is the liquid the pigments are mixed with in actual use, is a powerful reducing agent. After several years of experimenting the committee on paints of the American Society for Testing Materials decided that there was no similarity between the behavior of pigments in water and in oil paints; which might have been confidently predicted beforehand, and in fact was by many of the people who were familiar with paints and their behavior. But the claim that certain things are inhibitors of corrosion was eagerly taken up by the prople who had these things to sell, and they will keep it up as long as buyers can be found who will believe it.

We come back to the primary fact, that if we can keep air and moisture from iron it will not rust, and if these get to it, it will. So we must endeavor to cover the metal with an impervious film, which is difficult; but if we come near doing it, even if we do not reach perfection, we shall retard corrosion; we may retard it a great deal.

Red Lead.—Commercial red lead is essentially a mixture of true red lead, Pb_3O_4, and varying amounts of lead monoxide. The best red leads for painting purposes contain high percentages of true red lead, although even as much as 15 per cent. of lead monoxide may be present and good results be obtained.

In the manufacture of red lead the starting material is lead monoxide. This lead monoxide is subjected to a temperature of about 900° F., for a sufficient length of time, and at this temperature it takes up oxygen and is converted into true red lead. The lead monoxide used in the manufacture of red lead may be of varying origin. Inasmuch as the character of the red lead depends very much on the original lead monoxide, it is desirable to give some little attention to the methods of production of lead monoxide.

In the older works describing the manufacture of lead monoxide two distinct kinds are referred to. One is known as litharge and the other as massicot. Originally litharge was the by-product obtained by the oxidation of silver-bearing lead. During this oxidation, which was conducted at a high temperature, the oxide formed from the lead was in a molten condition and flowed off the metal, and when it solidified, it was more or less of a crystalline or massive character, hence the name "litharge." The temperature of the formation of this litharge was therefore above the melting-point of the oxide, and this fact distinguishes litharge from massicot. If, however, lead is melted and exposed to the air, a yellowish dross appears on the top of the lead, and by continual agitation of the lead and exposure to the air practically all of the lead can be converted into an oxide, which has not been fused during the process of manufacture. In the main, therefore, the distinguishing characteristics of litharge and massicot are that in the manufacture of the former the oxide of lead has been melted, while in the latter the temperature has not reached the melting-point.

Physically these two products may not differ much after they have been put through a grinding operation, but originally they differ considerably in appearance. In the manufacture of litharge under proper conditions the solidified mass of lead oxide shows a peculiar property of swelling on cooling and separating into beautiful reddish-brown flakes. From this appearance the product is often sold in this shape as "flake litharge." Flake litharge is produced from the molten oxide of lead which flows from what is known as the cupel furnace, which is used either in its preparation or in connection with the recovery of silver from lead. Flake litharge may also be produced, however, in an ordinary reverberatory furnace by carrying the oxidizing temperature sufficiently high so that the oxide of lead formed is in a slightly pasty condition. If a flake litharge is finely ground it assumes a buff color, which in some cases indicates the presence of a small percentage of true red lead formed during the cooling of the litharge.

Massicot, being produced at a lower temperature and subjected to more or less attrition during the process of production, is not so characteristically crystalline as litharge. Close examination of it, however, shows that the real difference between these two products is not so great as would appear. Custom consequently in the United States has led to the use of the term "litharge" as covering monoxide of lead (PbO) no matter what the method of production may have been. Most of the litharge used in the production of red lead is obtained directly from metallic lead. It is the custom, however, also to use clean lead drosses and waste white lead products for this purpose.

White lead at the temperature at which red lead is produced readily loses all of the carbonic acid and water contained in it and makes very suitable material for the production of red lead.

When white lead only is used for the production of red lead a form of red lead often called "orange mineral" may be produced. Inasmuch, however, as the composition of orange mineral is almost identical with that of red lead, particularly as to the composition of its components, it is proper to speak of orange mineral as a species of red lead. Really the only distinguishing feature is the characteristic color. A red lead that has a distinctly orange tone may be considered an orange mineral. The color of red lead differs through a fairly wide range. It may be deeply red even with a suggestion of a blue tone or it may have a light red color suggestive of orange. In the main these differences are due to the fineness of the product, the coarser product being deeper in color as compared with the lighter color of the fine product.

Chemical Considerations.—The expression "true red lead" is apt to occasion confusion. A commercial red lead made as indicated above contains varying percentages of true red lead, and yet as commercial products they may be strictly pure. Usage has extended the name "red lead" to products which may contain as much as 50 per cent. monoxide and in some cases to products containing even a higher percentage than this. There is no established usage determining when a litharge may properly be called a red lead. Therefore the expression "true red lead" is simply to indicate that component of commercial red lead which has the composition Pb_3O_4.

The fact that commercial red leads contain varying percentages of lead monoxide has led some writers to conclude that what might be called "true red lead" does not correspond to the formula Pb_3O_4, but rather to the formula Pb_2O_3. The existence of a compound of the latter composition is, however, somewhat doubtful. If it exists at all it probably is not produced by the oxidation of litharge at the conversion temperature. The reasons for doubt as to the correctness of the formula Pb_3O_4 will vanish if the following facts are considered.

In nearly every case it will be found that in commercial red leads the calculated percentage of Pb_3O_4 is proportional to the fineness of the product. In other words the finer the product, the higher the calculated percentage of Pb_3O_4 present. If a red lead containing, say 25 per cent of lead monoxide, is ground fine enough and then subjected to a cooling temperature, there is a further absorption of oxygen and an increase in the percentage of true red lead contained.

The subdivision of the litharge, however, is not the only factor which influences the ease with which it can be converted to red lead of high oxidation. The presence of impurities, particularly sulphates and sulphites, act as inhibitive agents, and the degree of oxidation obtainable is less in proportion to these impurities. Thus a litharge containing 2 per cent of lead sulphate seems to have a limit in its convertibility into red lead and the highest oxidation obtainable may be in the neighborhood of 93 or 94 per cent of true red lead.

If, however, a very pure lead monoxide is used and care is exercised to prevent contamination during the coloring, the oxidation may be carried as high as 99 or 100 per cent and a product obtained which corresponds closely to the formula Pb_3O_4.

Red lead contains a certain amount of oxygen which is valuable in chemical reactions for producing an oxidizing effect. From the similarity of this oxidizing action to what occurs in the case of manganese dioxide, the custom has arisen of calling this oxygen the "available oxygen" which represents the amount of oxygen present in excess of what is necessary to combine in the lead and form a monoxide. In the analysis of red lead the usual method is to determine the percentage of available oxygen, and having determined this, calculate to the true red lead, Pb_3O_4. The most approved method is the following:

THE DETERMINATION OF "TRUE RED LEAD."

Solutions Required.—1. "*Red Lead Solution.*"—Weigh out into a 1300-cc. beaker, preferably of Jena glass, 600 grams C.P. "tested purity" cryst. sodium acetate and 48 grams C.P. potassium iodide. Make up a solution of 25 per cent. acetic acid, by mixing 150 cc. C.P. glacial acetic acid with 450 cc. distilled water. Now pour about 500 cc. of this 25 per cent. acid into the 1300-cc. beaker, above mentioned, reserving the remainder. Warm the beaker on the steam bath, stirring occasionally, until a clear solution is obtained. Cool this solution to room temperature, and pour it into a 1-liter graduated flask. Then add enough of the reserved 25 per cent. acetic acid to make exactly 1000 cc. and mix thoroughly.

2. 1/10 *N. Sodium Thiosulphate Solution.*—Weigh out into a large beaker 25 grams C.P. cryst. sodium thiosulphate, add 400 to 500 cc. distilled water and stir until dissolved. Wash this solution into a 1-liter graduated flask, make up to the mark with distilled water and mix thoroughly.

Each 1 cc. of this solution is equivalent to about 3.48 per cent. true red lead (using 1 gram charge) but its exact value should be determined by standardizing against pure iodine, or better, against a standard sample of red lead, the "true red lead" content of which is accurately known. The strength of this solution gradually decreases upon standing. It is a good plan, therefore, whan analyzing a sample of red lead, to run a parallel determination, with the standard red lead, thus ascertaining the exact strength of thiosulphate solution. This procedure consumes but little extra time and will often prevent error.

3. *Starch Indicator Solution.*—Weigh out 3 grams of ordinary starch into a small beaker, add about 50 cc. cold distilled water and mix to a thin paste. Measure into an 800-cc. beaker 500 cc. distilled water, heat to boiling, and pour into it slowly, with constant stirring, the previously prepared starch paste. Then boil for two minutes, stirring and add 5 to 6 drops of oil of cassia. Allow to stand overnight and decant the clear supernatant liquid into a stock bottle. When prepared in this way the solution will keep indefinitely.

Method.—Weigh 1 gram of sample into a 300-cc. Erlenmeyer flask. Add a few drops of distilled water and rub the mixture to a smooth paste with a glass rod. Then add 50 cc. of the "red lead solution" and continue rubbing with the glass rod until nearly all the red lead has been dissolved. Remove the rod from the solution and wash it off with 25 cc. of distilled water, making sure that all washings run into the flask. Titrate at once with the 1/10 N thiosulphate, adding the latter rather slowly and keeping the liquid constantly in motion by whirling the flask. When the color of the assay has been reduced to a light yellow, examine it carefully for undissolved particles of red lead. If present, they can often be dissolved by shaking the flask for a short time, but if they dissolve too slowly, they should be crushed by rubbing again with the glass rod, until completely dissolved. The rod should then be removed and washed with a few cubic centimeters of water. After the addition of thiosulphate has reduced the color of the assay to a very pale lemon tint and care has been taken to see that solution of the red lead is complete, add 2 cc. of the starch indicator solution. The assay should then turn blue. Now finish the titrating by adding the thiosulphate solution, drop by drop, shaking the flask thoroughly after each addition, until the blue color disappears.

Calculation.—Suppose, for instance, that a red lead sample by this method requires 24.8 cc. of thiosulphate solution, and that the laboratory standard red lead requires 26.5 cc. thiosulphate.

Then the per cent. "true red lead"—

$$\frac{92.00}{26.5} \times 24.8 = 86.1 \text{ per cent. "true red lead."}$$

Notes.—Before analyzing a coarse sample, "glassmakers' red lead," for instance, it is necessary to grind the sample, thus rendering it more readily soluble. As a rule, it is not necessary to secure complete solution of the sample before beginning to titrate, for it will generally be found, by the time the titration is nearly finished, that the sample has entirely dissolved. Occasionally, however, a sample dissolves very slowly. In this case titrate until nearly all the free iodine has been used up. Then warm gently, not over 40° to 50° C., agitate until the solution is complete and finish the titration as usual. The loss of iodine, owing to its small concentration, will be inappreciable, provided that the heating is not too prolonged.

Never attempt to hasten solution of the sample by warming if much free iodine is present, as this will cause loss of iodine and, consequently, too low a result.

The temperature of the "red lead solution" when used, should be the same normal room temperature, say 20° to 25° C. If colder than this, lead iodide is apt to separate out. In this case, however, it may be redissolved by warming gently.

The "red lead solution" should be kept in a moderately cool, dark place, but even then, however, it may gradually decompose, with liberation of iodine. The error thereby introduced in the determination is inappreciable, if the thiosulphate is freshly standardized, before use against a standard sample of red lead, as recommended.

The main consideration, in this method, is to see that the determination is run in exactly the same way, and under exactly the same conditions as the standardization of the thiosulphate, by means of the standard sample of red lead. Then any small errors in the determination will be offset by similar errors in the determination.

Theoretical factor for $\frac{N}{10}$ $Na_2S_2O_3$ to $Pb_3O_4 = .03425$ per cc.

It may be added that the attraction between red lead and oil appears to be so great that the last traces of oil cannot be removed by solvents; hence, if the red lead be a pigment which has been extracted from oil, the small amount of oil which remains will affect the analysis. At all events, such extracted red lead shows about 1 per cent. less Pb_3O_4 than the original pigment, and allowance must be made for this.

A very simple method, assuming the red lead to contain no carbonate of lead, is to ignite the red lead in an oxidizing atmosphere until fusion is just obtained, the loss on ignition corresponding to the available oxygen.

Red lead is sometimes spoken of as "lead orthoplumbate," on the assumption that its constitution is represented by the following equation:

$$Pb_3O_4 = 2PbO + PbO_2.$$

On this assumption red lead is supposed to contain PbO_2 as a constituent, and sometimes specifications for red lead are based upon the percentage of PbO_2 obtainable from it by treatment with nitric acid, by which red lead is decomposed with a formation of lead nitrate and PbO_2 or lead peroxide. In fact this is the usual method of preparing lead peroxide for use in the arts. On the other hand the available oxygen may be determined and calculated to lead peroxide.

Varieties of Red Lead.—There are a great many varieties of commercial red lead, the difference between them being determined by the uses to which they are put. Red lead is used for the manufacture of flint glass. Here a high oxidation is not desired, as that would mean a very fine product and in glass manufacture dust from a fine product is objectionable. The use of red lead in preference to litharge in glass manufacture is on account of the available oxygen present, which helps to burn out the impurities in the mixtures.

Red lead is used in the making of storage batteries. Here the physical characteristics and the purity of the product are important. A red lead is desired that will form the right kind of paste and that will not be subject to flaking off or disintegration during the recharging and use.

In the manufacture of eosine vermilions and similar products, the color of the red lead, both in the original state and when tinted, is an important factor. Usually the object is to use red lead which will take as little organic coloring material as possible to obtain the desired color. Freedom from lead monoxide is desired here, and these vermilions are often mixed with oil and varnish, and an excess amount of lead monoxide is apt to occasion hardening.

The red lead used as a drying agent in the manufacture of varnishes does not usually contain a high percentage of true red lead. The important thing here is purity. As to whether litharge or red lead should be used in the manufacture of varnish, opinions differ. It seems, however, that red lead is more slowly dissolved than litharge and apparently is less apt to form soaps or insoluble compounds which separate out in a cloud on standing. This is particularly true in the use of red lead in the manufacture of boiled linseed-oil.

Besides these uses, red lead is important as a pigment, chiefly in paints for protecting iron and steel from corrosion. For more than a hundred years it has been considered valuable for this, and if there can be said to be a standard paint for such use, it will be agreed to be red lead. It has, however, been a difficult material to use; moreover, it is nearly all lead, which is costly material from a painter's standpoint, and is made from it by several successive operations, each of which costs something, so that it makes a rather expensive paint; its popularity in spite of these objections indicates substantial merit.

Pigments are commonly thought of as solids in powdered form which are only mechanically mixed with oil and have no action on the vehicle. It is probable that all pigments do in some way react with the vehicle; and that those which act least are the less valuable; but naturally exception will be made to any which combine with it to make soluble or brittle compounds; such solids should not be used as pigments. However, we expect a paint to be a mixture of solid and liquid ingredients which will continue to maintain its generally fluid character until after it has been applied. To this red lead has been an apparent exception; when mixed with oil the paint soon begins to grow thick, viscous and ropy and in spite of this increase in viscosity the pigment rapidly settles to the lower part of the container, most of the oil and relatively little of the pigment being above the thick and heavy portion. As everyone knows, paints are usually mixed by machinery and ground through a mill; but red lead has been supplied to the painters in the form of a dry powder, and mixed by hand, stirring it into the oil with a stick immediately before using; and even while using it has been common to stir it from time to time. When a paint is ropy it is difficult to brush out to a good film, and it shows brush-marks which are alternate ridges and valleys; such a surface not only looks badly but does not resist abrasion as well as a smooth one; and the excess material in the ridges (which is, obviously, in the aggregate a large proportion) might better be used on a fresh surface; that is, it is wasteful. But in spite of all these serious objections the belief that red lead is a valuable—perhaps the most valuable—prevention of corrosion has become a widespread conviction; and its imperfections have been tolerated in so far as they cannot be overcome.

Red lead is made from the protoxide by roasting it in a reverberatory furnace; if the litharge is crystalline it is naturally coarse, and if it is in the form of massicot it commonly contains coarse particles; if coarse, it is necessary to grind it, either in water or dry; but even when ground it is likely to contain some coarse particles. The fine dust oxidizes completely into Pb_3O_4; the coarse grains do not do so—a central core of PbO remains. Therefore, the finer the litharge is the higher will be the proportion of true red lead, unless it contains $PbSO_4$ or some other material which interferes in some way with the oxidation. The painter, in times past, has not concerned himself with chemical problems; but he has always demanded fineness in pigments, so that by selection the red lead used for paint-making has been the more highly oxidized, leaving the lower grades for glass-making and the like. And it was found that the finer and more completely oxidized material showed less of the ropy and other objectionable qualities, until at last it appeared that it is the PbO or unconverted litharge which acts strongly on the oil, and the true red lead is no different in this respect from any other good pigment. It is, however, difficult as a manufacturing problem to completely convert PbO into Pb_3O_4; excessive grinding costs money, and a very finely ground litharge does not work easily in the furnace and is difficult to oxidize to a finish. But the standard of painters' red lead advanced from 60 per cent. Pb_3O_4 to 80 per cent., then to 85 per cent., and considerable amounts were made of 90 per cent.; and when structural steel began to be used in large amount on the Panama Canal the United States army and navy engineers began to call for 94 per cent. Paint made from this would remain without hardening for at least twenty-four hours, and was better in every way; and at the time of writing this it may be said that 94 per cent. Pb_3O_4 is standard for painters' red lead.

Recent improvements in grinding machinery and in mechanically operated roasting furnaces have made it commercially possible to make red lead which contains 98 to 99½ per cent. Pb_3O_4; and so inactive toward linseed-oil is this that thousands of tons of it have been sold in paste form, i.e., ground in just enough raw linseed-oil to make a stiff paste, like paste white lead. With this step red lead may be said to have become a perfectly normal pigment; paint made from it works easily and makes a smooth, glossy coating, uniform in thickness and appearance.

This paste contains about 7 per cent. of oil; white lead paste has 8 per cent., but red lead is heavier and consequently has less bulk and requires less oil.

The question naturally arises, is a highly oxidized red lead as good as or better than a red lead, of, say 85 per cent.; and it is not a simple question to answer. There is no doubt that good results were obtained in former times when it contained a considerable proportion of litharge; but it is also true that failures were not uncommon. Only good results are commonly thought worthy of record; the failures are remembered by the older men, but may not be known to those whose experience is with the newer and better material. And it is always possible that the better of the older records were based on rather high-grade material, for the fine pigment was always high grade; and this seems likely; but perhaps not.

The radically difficult point is this: All experience shows that it is important to have paint applied well, in a uniform, smooth, even coating with no uncovered spots, however slight, which may happen with imperfect work, and none where it is unreasonably thin, as it may be in the grooves of pronounced brush-marks; in all these and other similar respects, which are summed up as fine working quality, this high-grade red lead is much superior to the older variety; and if the lower grade were as well and perfectly applied as the other naturally is, it would certainly give better results than it ordinarily has afforded, and in fact might prove to be equal to or even better than the newer product. So that as to the quality of durability it is not easy to say; for the real durability may be masked by the way the painter applies it, and that is affected by its working quality, which is another thing.

On the other hand, what interests the man who pays for the painting is the length of time the protection is given and he may not care whether this is due to increased durability of material or improved working quality; what he wants is results. From this standpoint there is no question that the more perfectly oxidized red lead is the best. It is also the cheapest, because, with equal weights, it covers considerably more surface and can be applied with less labor.

There is, however, some direct evidence that it is really more durable. In the Havre de Grace bridge test, conducted with great care by the American Society for Testing Materials, the most durable of all the paints tested (in an eight-year test) was a very high grade red lead; the other red leads, which also were excellent, lasted in proportion as they were more highly oxidized. It may be said that it is a matter of common knowledge that red lead paint, exposed to the weather, is usually rapidly discolored; but a 99 per cent. red lead is of relatively permanent color, so that it is now used as a signal red. This clearly indicates permanence. The same has appeared in all the numerous tests which have come under the observation of the writer; and in these cases the extreme care taken in application eliminates the advantage of better working quality.

In the proportion of pigment to oil in red lead paints the practice is variable. As it was formerly customary to mix them in small qualities, directions were given to mix so many pounds of dry pigment to each gallon of oil. The highest amount in ordinary use was 33 pounds, though as high as 40 pounds is on record; from 33 to 28 pounds was high-class practice; 25 pounds was common for bridge painting; as low as 20 pounds has been often specified for bridge work; and the writer has known of the use of a paint containing as little as 6 pounds of dry red lead to a gallon of oil; this was by a contractor who used it on a contract calling for "a coat of red lead paint." It passed inspection. The old 33-pound formula had a high reputation; but the paint, if made from an 80 per cent. red lead, rapidly became thick so as to be unworkable; so to two-thirds of a gallon of such paint was added one-third of a gallon of straight lampblack-in-oil paint containing about a pound of lampblack in a gallon, and this made a paint of excellent working quality containing about 22 pounds of red lead and about 6 ounces of lampblack to a gallon of oil, the lampblack being added simply to keep it sufficiently fluid, and incidentally to give it a dark-brown color, nearly black (6 ounces of dry lampblack is contained in a little less than 2 pounds of paste lampblack). This was the origin of a well-known railroad formula of 22 pounds red lead to a gallon of oil, the lampblack not being reckoned as of any value—a considerable error. The facts appear to the writer to be that 33 pounds to a gallon (which makes 40.75 pounds of paint weighing 28.1 pounds per gallon, containing 22.75 pounds of dry red lead in each gallon of paint), makes a hard paint (red lead paint never is brittle), suitable for painting water-tanks and the like; the larger proportion of pigment prevents the paint from softening under the action of the water; red lead seems to have considerable effect in this way. This is also a good bridge paint for warm and damp climates. For more general use 28 pounds of pigment to a gallon of oil makes a more elastic paint, better suited to resist the heat of the sun, especially in less moist exposures; it makes 35.75 pounds of paint weighing 25.8 pounds per gallon and containing 20.2 pounds of dry pigment in a gallon. The more common railroad formula of 25 pounds to a gallon makes 32.75 pounds of paint weighing 24.4 pounds per gallon and containing 18.6 pounds pigment in a gallon.

In general, with red lead as with all paints, the effect of the sun and weather is to harden the outer part more than the under coat; therefore when applied the undercoat should be harder than that which is over it. Otherwise the outer coat is liable to develop cracks, "elastic undercoat cracks" the painter calls them; not going entirely through, but making weak places.

By using 98 per cent. red lead (paste) workable mixtures may be made exceeding 33 pounds pigment to the gallon of oil; as high as 40 has been used for special work. This will call for 60 pounds paste to each gallon of oil, making nearly 2¼ gallons of paint. This works well with the paint brush, and is suitable for surfaces to be riveted or bolted together, also for tinplate valleys and gutters on roofs; these require a very heavy coating.

Red lead has a very brilliant color, but little staining power; one part of dry lampblack in 500 of red lead changes it to a coffee color, and 1 per cent. to a dark chocolate.

We know very little, accurately, as to the action which takes place between lead pigments and linseed oil. More than fifty years ago a celebrated Belgian chemist named Stas in an official report to the Jury of the International Exhibition of 1865 expressed the opinion that the lead hydrate in white lead saponifies the oil, and thus lends toughness and permanence to the film; to this he attributed the superiority of lead paints. But in the same report he cites with approval a reference to Liebig, another distinguished chemist, saying that "Liebig was the first to show that lead oxide can dissolve in a somewhat large amount of oil without saponifying it." In white lead paste there is five times as much lead hydrate (assuming the portion uncombined with carbonic acid to be hydrate) as would completely saponify all the oil present; yet we may with solvents remove this oil and but a small portion of it has undergone any change; even its acidity has not diminished, but rather increased. So with red lead and oil; even when whese have formed a hard dry mass, not greasy to the touch, it may by rubbing in a mortar be reduced again to a paste, and the extracted oil, though it contains sometimes more than 10 per cent. of its weight of lead in solution, is not of high viscosity and does not appear to contain this lead in the condition of a soap.

When a heavy shaft is revolving, supported by the concave surface of a metal bearing-box, friction is lessened by using oil, which forms a layer between the moving and the stationary surfaces. When we consider the great pressure exerted by the weight of the shaft, to which is added the pressure of the belt, we must see that the attraction between the oil and the solid surfaces must be enormous or the oil would not be there; it would be squeezed out. It must be in an excessively thin film, but it must be a continuous film. Thus it appears that while the metal has little or no attraction for the oil at a considerable distance, the attraction at an inappreciable distance is very great, so that the revolving shaft is really supported by the film of oil, notwithstanding the great force which is constantly applied to remove it. No one supposes this to be a chemical action.

Now let us consider the thickness of oil film which surrounds the particles of pigment. In red lead paste the oil is two-fifths and the pigment three-fifths of the volume, hence every particle of pigment may be supposed to be surrounded by two-thirds of its volume of oil. If we consider the whole space divided into cubes, with a cubic particle of pigment in each one, the diameter of each particle is to the diameter of the total space assigned to it as the cube root of three-fifths is to the cube root of one, and the distance of the solid particles is, roughly, one-fifth their diameter. If these particles are, as I think has been shown by measurement, not more than one one-hundred-thousandth of an inch in diameter, no part of the oil is more than one-millionth of an inch from the surface of the nearest solid particle; which may be regarded as comparable to the " inappreciable distance " (unknown distance) of the revolving shaft problem. That is, there is an attraction of unknown but great intensity between the oil and the pigment; which may be, in the last extremity, more than that between the oil and the solvent (ether) with which we try to remove it. This accounts for the impossibility of extracting the last traces of oil in paint analyses; and may indicate that surface attraction may have some thing to do with the hardening of a litharge-containing red lead in oil. The matter of solubility of lead in oil is at present obscure, but the drying of a film of high grade (98 per cent. Pb_3O_4) red lead and oil is doubtless caused by the atmospheric oxidation of the oil, complicated in this by surface attraction between the oil and pigment, in which red and white lead exceed all other pigments; as is proved by the fact that oil will displace water from a mixture of water with these lead pigments, even at ordinary temperatures.

Unreliable Reports.—Actual use on a large scale is the best test of a paint, but it is very difficult to be sure of your conclusions even from such use. The chief metal structures which are accessible for observation are bridges. A competent man who should have charge of the painting of a large number of these ought to be able to arrive at valuable results, but men capable of making critical study of so difficult a matter are rare, and are usually too valuable to be put to such work. Tenure of office is often brief, as compared with the long time needed for such investigations, and very often the corporation which owns the bridge has adopted some one paint as a standard and this seems to be able to prevent a fair judgment. The men who are in charge become prejudiced in favor of their paint and can see no defects in it, and nothing good in anything else. The very workmen share in this feeling, and they have learned how to use their standard paint to the best advantage, and it is applied better than any other. They, in many cases, retouch work from year to year, which is quite right, but no record of such work is made and the bridge is reported as having stood so many years without repainting, while a bridge painted with some other material is condemned as soon as it begins to look shabby. The result is that one man who has charge of the bridges for one road reports that a certain paint is satisfactory and better than any other, while the next man on a parallel road condemns the first man's paint and extols a paint which the other found wanting. Both mean to be right; neither is capable of knowing the truth. Nothing is more natural than the desire to think well of one's own work, and in practice I would commonly prefer the real opinion, if it can be got at, of a paint manufacturer to that of a user, for the former has every incentive to find out the truth; the trouble with him is that he is disposed to think, and especially to speak, most favorably of the thing which sells the best. There isn't much money in being a missionary or a reformer. Sell people what they think they want, not what you think they ought to want, is the business maxim; and this feeling interferes with testing paint or anything else.

It is of no importance to try to compare service tests of paints unless the paints are well applied to surfaces in fairly good condition, for an indifferent paint well put on clean metal will last longer than a much better paint poorly applied or put on over rust and dirt. It is also of no profit to make a service test with 1 or 2 gallons of paint. The workman should have enough paint to use so that he will become familiar with its peculiarities, and this is no small undertaking. An experienced and unusually intelligent master-painter was using a new paint, of which his men had used perhaps 10 barrels. He said his men were applying it on an average to 1200 or 1400 sq. ft. each per day. In two other shops with which he was familiar the amounts used were approximately 150 and 500 barrels of the same paint and their men averaged 1600 to 2000 sq. ft. He said his men were gaining on it, and in time there was no reason why they should not do as well; but it took a long familiarity with a new paint to get the best results with it. Now, if it takes 2 or 3 barrels of paint per man to get this result, what are we to say of a test of a gallon or two? No doubt an experienced painter can tell some things about a paint after using a pint of it, but not enough to warrant final conclusions if it is a fairly good and ready-working material.

Paint Tests.—Paint may also be tested with sets of test-plates. If such experiments are made with sufficient care they are valuable, and as matters actually stand, this is the most available way of getting reliable results. But it is not an easy or simple thing to get at the truth in this way. I would say in the first place that the plates should not be too small. I have myself used plates measuring twelve inches by twenty, and I think they would be better if they were larger. They should not be of thin metal, never by any chance of sheet iron, but thick enough so that they will not bend or spring under any pressure which is likely to be applied to them. They should be of pickled and cold-rolled steel, unless a test of the behavior of paint on other metal is in question, and perfectly free from scale and rust; all exactly alike in these regards. I mark plates with a steel numbering stamp on the middle of each side and also mark the same plates with a series of saw-nicks on one edge; these latter are perfectly reliable and easy to find; the former are more easily read and sufficient in most cases. The paint or varnish used should be in its best condition and applied under favorable conditions of temperature and weather and after each coat the plate should be hung up to dry for at least a month. To facilitate hanging up these plates a hole should be bored in each end of the plate, about half an inch in diameter, and the plate should be hung alternately from these holes as alternate coats are applied. For the reasons already given it is necessary to apply a striping coat along the margins of the plates between the first and second coats, and if three coats are applied it would be well to apply a second striping coat between the second and third or else after the third, this I have not myself practised, usually making two coat tests; the striping coat requires thorough drying. Unless the test is simply a weathering test, the plates should be hung up in a room where the air is ordinarily pure and dry for six months after the painting is completed before the test begins; but if they are to be used in a weathering test, they may be exposed as soon as they are reasonably dry and it is certain that all are in about the same condition. It is very desirable that the thickness of each plate should be measured with a vernier caliper before painting at certain designated spots; for example, the caliper may be applied at a point 1½ inches back from the edge and 4 inches to the right of each corner. Record is made of these measurements, and when the last coat of paint is dry the thickness may be again measured; if the plate is painted on both sides, which I think is the better way, the difference in measurement, divided by two, gives the thickness of the paint- or varnish-film.

Electrical Tests.—If the caliper can be depended on to read the ten-thousandths of an inch this measurement will be important, especially if the porosity of the coating is to be determined by its electrical insulating power. If this test is made it must be remembered that the ease of insulation varies with the square of the thickness of the coating, and that only the direct current is to be used, because with the alternating current there is danger that the plate will act as a condenser and conceal the real voltage. Such electrical tests if made at different periods during the time test will be of much interest; so far as I know this has never been done. Coatings for special uses should, of course, be tested after being applied in the way which is best suited to develop their possibilities; if, for example, we are to test a baked coating against an ordinary paint or varnish, we should bake it under favorable conditions, but we would not therefore bake the competing preparations, which should be applied in the usual manner.

Protect Edges.—In any method of exposing plates which I have ever seen, it is impossible to avoid injury to the edges of the plates, and as the marginal portion of a plate of ordinary size is a large proportion of its total surface, we should either start out by saying that we will not count as part of the test the strip, say an inch or an inch and a half wide, along the edge of any plate, or we should take some extraordinary measures to prevent such injury. This is especially important with plates immersed in the water, which are often injured more by floating objects carried by tides and currents, perhaps far below the surface (ice, for example), which because of their weight and rigidity strike severe blows and thus mechanically remove the coating, no matter how firm it may be. I have thought that it might be a good plan to set each plate in a wooden frame, like those on the slates of school children; these would give considerable protection. I have not known this to be done, but I see no objection to it. This danger of marginal injury is one of the most serious objections to plate tests.

A most serious matter is the difficulty of knowing that the plates are all alike. When a coating for any reason begins to fail, and even when perfectly new, if it is, like almost all coatings, a little porous, it is obvious that if we have two plates coated exactly alike, and the metal of one is more easily corroded than the metal of the other, the coating on the former plate will appear to perish sooner than on the latter. Chemical tests will, of course, show differences of composition if there are any, but I do not think it very difficult to get plates of the same chemical composition, but the physical or molecular structure has great influence, and I do not know how to determine this condition. That its effect is real is shown by the following facts: Copper pipe is used on the ships of our navy for fire mains and other purposes; this is made in sections with flanged ends. The flange is made by slipping over the end of the pipe a tightly fitting brass ring, and the projecting end of the copper pipe is expanded by hammering, so that the ring cannot come off. This hammering, of course, draws out the copper and disturbs its structure without affecting its chemical composition; as the pipe is composed of copper, as nearly chemically pure as can be commercially obtained, there may be said to be no chemical difference in its different parts. These sections of pipe were coated with a varnish enamel all alike.

Influence of Molecular Structure.—After prolonged use it was found that the coating was in good condition except near the flanges, where the metal, though it had not been actually hammered, had been drawn by the blows on the adjacent ends. This occurred not in one but uniformly in very many instances, so that the inference that the liability of corrosion of the copper is dependent on its molecular structure was unavoidable. If this is true of copper, it is probably true of steel and iron; and the effect, instead of being inconsiderable, is very marked. It is easy to see that differences in temperature while rolling steel plate or bars may make difference in structure, as do also differences of thicknesses or section. This is, in fact, well known, for a steel wire is three times as strong as the same metal rolled into a bar. It is then possible that two test-plates which look alike may vary by an important amount in resistance to corrosion, and this at once introduces uncertainty into the most carefully conducted test. This is, in fact, a valid objection, so far as it goes, to all test-plate experiments; yet the practical difficulties of getting fair experiments made on a large scale are probably vastly greater.

This subject is more fully treated by Sang (Corrosion of Iron and Steel, 1910), pp. 40–80. It is well known that the metal around punched holes will rust more rapidly than around drilled holes; and in general, steel which has been subjected to severe strain is thereby changed in its resistance to corrosion. "Carelessness of manufacture which tends to heterogeneousness is an invitation to corrosion and in itself goes far to explain why modern steel, which is tortured into shape at such a high speed that the molecules are not permitted to readjust themselves, is said to be more corrodible than the metals produced a generation ago; in those days iron was produced in small quantities, without the addition of other metals, and was rolled slowly and allowed to cool naturally."

The foregoing discussion of the way to conduct tests is preliminary to the following account of some tests made by the author, which will be followed by some remarks on varnishes and varnish paints, as used for the protection of structural metal. The substance of these experiments has already been published in the Transactions of the American Society of Civil Engineers, but it is worth while to bring together the whole in a somewhat more connected form.

In 1895 I had eighty-four plates prepared for a test in sea-water. Permission was obtained from the U. S. Navy Department to make use of the facilities of the New York Navy Yard, and I was especially fortunate in having the cordial assistance and co-operation of Naval Constructor F. T. Bowles (afterward Chief Constructor and Rear Admiral), in carrying out the work after the plates had been made ready. The plates were coated at the works of Edward Smith & Co., who, moreover, paid the expenses of this and the following series of tests, the most extensive and I believe the most important that had been made up to the year 1900. Thirty of these plates were of aluminum, and were furnished without cost by the Pittsburgh Reduction Company, makers of aluminum. Prior to this time aluminum had been used in marine work and had been condemned, as the sea-water attacked and dissolved it, but pure aluminum had not been used, and it was desirable to know whether the pure metal or some alloy of known composition might not be available, and also, of course, what coating was best for its protection. Five series of aluminum plates and alloys were provided, ranging from 75 per cent. aluminum to 99½ per cent., which was at the time the purest aluminum which could be commercially prepared. There were six plates in each series and a corresponding number of varnish coatings were applied, so that each of these coating compounds was applied to one of each of the different kinds of aluminum plates. In this way the different alloys could be compared and so could the different coatings. The same coatings were applied to some of the steel plates, but the greater number of the latter, and the fact that they were all of one metal, made it possible to use a much greater number of coatings. The general plan, which was carried out more fully in the later set of tests, was to determine the comparative value of pure linseed-oil as a vehicle, then of a varnish containing a maximum proportion of oil to the unit amount of resin, then a medium varnish, then one having a minimum proportion of oil; and as different resins may have varying values, to duplicate and in fact to triplicate those varnish experiments with varnishes made of resins of three different classes. The resins selected were Zanzibar, Kauri, and Manila. The latter is said to be a "recent" resin, that is, one taken from the living tree; Kauri is a semi-fossil resin, from trees of a species now living, but of no use except as it has lain buried in the ground for a long time and undergone chemical change; while Zanzibar is a fossil so old that the trees themselves have become extinct. The three resins are well known and are commonly regarded as types of the classes to which they belong. Besides these there were a few special paints or compounds tried, red lead and oil being one, and another the baked enamel known as the "Sabin Coating," which will be more particularly mentioned in describing the coating of pipes; also a special oleo-resinous varnish known by the trade name of Durable Metal Coating, in which a certain amount of gilsonite replaces a corresponding amount of vegetable resin. It is interesting to note that a varnish of very similar composition to this was used in the first really scientific sea-water tests of which I can find any record, by Mr. Robert Mallet, who made reports to the British Association for the Advancement of Science in 1838, 1842, and 1843; and such a varnish, with one other made entirely from fossil resins and containing a large amount of oil, were the best of all the different paints and coatings which he tried. His exposures were for a period of eighteen months and are worthy of study by any one interested in the subject. He was handicapped by lack of knowledge of the art of making varnish and paint, and of their practical use, but he approached the subject with a truly scientific spirit, and without unreasonable prejudice or interest. The aluminum plates were put in a cage or framework by themselves; the steel plates in two similar cages. Each cage or frame consisted of four corner-posts each about 3 ins. square and 4 or 5 ft. long; these were mortised into 2-in. plank ends which were about 2½ ft. square, and the tenons were held in place by wooden pins. Each of these corner-posts had grooves about ¾ in. deep and wide enough to receive the edge of a plate cut across one side every 2 ins., and these posts were so set that the plates could be slipped into these grooves like shelves, a couple of inches apart. In this way thirty plates would fill a frame 60 ins. long. After the plates were all in place they were prevented from sliding out by fixing a bar across each end of the set of plates parallel with the corner-posts, and the plates were moreover made tight in the grooves by little wooden wedges at each corner of each plate. It was not desirable to use any metal about the frames, for iron would rust out and there was danger that the vicinity of any other metal might induce galvanic action. These frames, when filled, were heavy and rather awkward to handle. They were suspended by substantial iron chains which went entirely around each cage lengthwise. The iron rods from which the links of these chains were made were ⅜ in. in diameter, and so severe was the corrosion that in some cases these chains, of which two were attached to each cage, were entirely rusted away, although the chains were "galvanized" or zinc-coated; and in consequence some of the plates were lost. In the first test fourteen steel plates were lost, as is shown by the table. This first set of plates was put in the water in January, 1896, and was taken out July 29, 1896, after six months' immersion. During this time they were suspended 5 or 6 feet below the level of the water, in the New York Navy Yard, in Brooklyn. The water here is foul because of the discharge of sewerage from the city, and the conditions are more unfavorable than they would be in the water of the open sea. The strong tide constantly stirs up the mud from the bottom. When the plates were finally removed for examination it was done in the presence of the Naval Constructor and of several well-known engineers and of representatives of the technical press. The reports in the following tables are substantially those made by the combined inspection of these authorities. It has been said that the ends of the frames in which the plates were suspended were of solid wood. After soaking in the water these ends swelled, thus separating the corner-posts more than they were at first, and in consequence the plates became loose. This caused considerable damage to the coatings at the corners where they were in the grooves, and the edges of the plates also suffered from abrasion by objects floating in the water. This, as has been already explained, is a serious cause of error, or at least made it difficult to arrive at just conclusions. Four-fifths of all the corrosion occurred along this marginal strip.

Among the pigments mentioned is one called by a trade name "Flamingo Red." This was included, although its composition was unknown, but consists in considerable part of a red coloring-matter derived from coal-tar, and it had seemed very permanent in the air. It did not prove to be of much value in these tests. It will be noted that some of the aluminum plates are said to have "one side baked" and that the steel plates are mostly made up in pairs in this first test. Of each of these pairs one plate was baked at a temperature of 215° to 240° F. for four hours or longer. The steel plates bearing the odd numbers were dried slowly at the ordinary temperature and the ones with the even numbers were baked. This was done because it was thought possible that baking might add to the durability of the coatings, but the result showed that while a special coating made to be baked on was durable, the baking of coatings not designed to stand a high temperature was on the whole injurious to them, more so to those which were naturally hard and brittle than to those which were more elastic. One very remarkable thing was observed, in this and the following tests, which can hardly be made to appear properly in a tabulated report or indeed in any kind of a report, which is that all these paints and varnishes (except the "Sabin Coating," which was baked on at 400° F., and thus stands apart from the others) soften when soaked for a very long time in water. They do not seem to dissolve, and in many cases the water does not penetrate to the underlying metal, but the coating becomes soft, and though it remains elastic it can be scraped off in large strips. If, however, it is not disturbed and the plate is set up in the air it will dry out and the varnish will become hard again and even lustrous. When it is soft it can be scraped off with the greatest ease, and this prevents its being useful for submarine work. Some of the varnish enamels were much less affected in this way than the varnishes themselves, but none were very resistant. It is obvious, however, that these same coatings might give satisfaction in places where they would be dry part of the time.

In the following table the letter "K" stands for Kauri (resin), "Z" for Zanzibar, and "M" for Manila, and the numerals prefixed to these letters indicate the number of gallons of linseed-oil which are combined with the unit amount, 100 lbs., of resin weighed before melting. For example, 20 K. means an oleo-resinous varnish made by melting 100 lbs. of Kauri resin and combining with it 20 gals., or 154 lbs., of linseed-oil. The compound was subsequently thinned with a suitable amount of spirit of turpentine, but as this is volatile, no mention is made of that in the abbreviation.

The result of this test was of so much interest that other plates

	SERIES I. Ninety-nine and One-half Per Cent. Pure Aluminum.	SERIES II. Ninety-eight Per Cent. Aluminum and Two Per Cent. Copper.
"Sabin Process" pipe-coating enamel, baked.	101. Perfect.	107. Perfect.
"Durable Metal Coating," one side baked.	102. Baked side, perfect. Unbaked side, three blisters, ¾ in. diameter. No general corrosion or roughening. The surface of the paint had lost its gloss. Coating good on edges of plates.	108. Baked side, one blister, ¼ in. diameter. Unbaked side, perfect.
Ultramarine Blue, one side, "Flamingo Red," one side, in 20 K. varnish, not baked.	103. Blue. Scarcely any corrosion, but shows roughening of coating and numerous pin-head blisters. Red. General condition good except near edges of plate; there, blisters on surface ½ in. wide along one-fifth the margin. Very little corrosion.	109. Blue and red about the same as 103, except that about twice as much surface was blistered. General condition good.
White zinc in 20 K. varnish, one side baked.	104. Baked side, about 2 sq. ins. in one place half covered with small blisters. No corrosion. Unbaked side, first-rate condition.	110. Baked side badly blistered in spots along the edges, amounting to about 6 per cent. of the total surface of the plate. Some corrosion under these. Unbaked side all right except that 1 per cent. of the surface showed pin-head blisters on a strip about ½ in. wide on one edge of plate.
Chromium oxide, in 20 K. varnish, one side baked.	105. Baked side, one blister 1 in. by ½ in., otherwise first-rate. No corrosion. Unbaked side, perfect.	111. Baked side, four central ⅜ in. blisters, numerous marginal ones about 1½ per cent. of plate. Very little corrosion. Unbaked side, first-rate condition.
Spar varnish, no pigment, one side baked.	106. Perfect.	112. Baked side, two central blisters, 2 and 4 sq. ins. and nearly all the margin ½ in. wide. Considerable corrosion. Perfect except where blistered, lustre good, etc. Unbaked side, two central blisters, ½ sq. in. and 1 sq. in., slight marginal corrosion, coating evidently thin on edges.

SERIES III. Ninety-eight Per Cent. Aluminum. (The quality known in 1895 as commercially pure aluminum.)	SERIES IV. Ninety-three Per Cent. Aluminum, Seven Per Cent. Copper.	SERIES V. Seventy-five Per Cent. Aluminum, Twenty Per Cent. Zinc, Three Per Cent. Copper, One Per Cent. Iron.
113. At one corner a break in the coating let in water and caused a blister of about 2 sq. ins. Coating rather overbaked and brittle, but elsewhere perfect.	119. Coating overbaked, cracked at corners by the wooden framework, and the sea-water made blisters at the corners, some of which were 3 sq. ins. Remainder of plate perfect.	125. Coating overbaked and brittle; badly blistered along the edges. All blisters under pipe-coating enamel are continuous and start from the edge. The middle of the plate was all right.
114. Baked side perfect. Unbaked side tough and adherent, except one small spot near the middle of the late, which looked as if the coating had been broken, and where corrosion had begun.	120. Baked side showed three blisters of about 1 sq. in. each, and some corrosion under these; otherwise all right. Unbaked side perfect.	126. Baked side badly blistered along the edge; 6 or 8 per cent. affected. Unbaked side slightly blistered along one edge: condition otherwise good. No corrosion.
115. Blue and red about alike. No decided blisters, but coating itself showed some signs of decomposition, especially the blue, which had a rough surface.	121. Blue and red about alike; about 30 per cent. blistered and corroded.	127. Blue, considerably blistered along the edges, mainly pin-head blisters. Little corrosion. Red, about the same but some large marginal blisters. The red had a smooth surface but the blue was rough.
116. Both sides in good condition, but showed some signs of incipient blistering about the edges.	122. Pin-head blisters along the edges; general condition all right.	128. Baked side, nine or ten blisters of about 1½ ins. diameter and considerable corrosion; remainder of surface good. Unbaked side, 1 per cent. of the surface near the edges, with small blisters showing some corrosion: the rest of the surface all right.
117. Perfect.	123. Baked side all right. Unbaked side, seven or eight small blisters but no corrosion. General condition good.	129. Baked side, a large number of groups (about 1 in. diameter) of small blisters with some corrosion; the rest of the surface all right. Unbaked side, much the same, not as bad.
118. Perfect.	124. Both sides badly blistered and corroded along the edge, about 10 per cent. of the surface. Where not blistered all right.	130. About like 124.

were prepared and coated. About three hundred plates were prepared and the time of preparation was nearly a year, so that it was late in June, 1897, before the plates were in place and the exposure actually begun. The greater part of these were steel plates which were painted in triplicate sets, with the intention of putting one set in the sea-water in the New York Navy Yard, one set in the Navy Yard at Norfolk, Va., and a third set in fresh water. The place finally chosen for the last was Lake Cochituate, Mass., part of the original Boston water-supply.

Besides these there were twenty-five plates of aluminum in each of the Navy Yard sets, but no aluminum plates were put in the fresh-water test because it is well known that pure water does not attack aluminum. It will be observed that in the tables already given the steel plates are numbered from 1 to 40, and the aluminum from 101 to 130. It was, therefore, decided to number the aluminum plates in this experiment from 151 to 200; the steel plates for the New York Yard from 201 upward; for the Norfolk Yard from 301 upward, and for the fresh-water set from 401 upward, and this was done. The aluminum plates were of two sorts, part being commercially pure aluminum, as pure as could be made in 1896, and the remainder were of aluminum alloyed with 5 per cent. of other metal. The plates numbered from 151 to 163, inclusive, in the New York set correspond to those numbered from 176 to 187, inclusive, in the Norfolk set, and are pure aluminum. Those numbered from 164 to 175, New York, correspond to 188 to 200, Norfolk, and are of the aluminum alloy.

Besides these regular sets of plates, a cage containing twenty-four plates, part steel and part aluminum, which had in 1896 been exposed for six months in the New York Yard and are described in the foregoing tables, were again exposed in the New York set. Half of these were lost by an accident in the New York Yard, but the remainder are described in the following table, pages 316–323, their numbers of course, being the same as in the table on pages 312, 313. To make them more prominent, they are also distinguished by the date, 1896, after the number.

STEEL PLATES. 1896 TEST.

White Zinc.	White Zinc.	White Zinc.	White Zinc and White Lead.
8 K. 11, 12. Hard and brittle, very few blisters or rust-spots. Outer coat separated from the under-coat when scraped, leaving the latter on the metal.	8 Z. 23, 24. Poor; thin, brittle, many rust-spots.		
12 K. 9, 10. No. 9. A large number of pin-hole rust-spots on one side. Hard and brittle. No. 10. No rust or blisters, hard and brittle. These not easily scraped off while wet.			
20 K. 7 8. Good; a few small rust-spots where coating was thin, near the margin; not easily scraped off when wet. Coating brittle.	20 Z. 21, 22. Good condition, thin and brittle near the margin; could be scraped off with difficulty when wet.	20 M. 15, 16. Good condition, except where the coating was thin and brittle near the margin, where there was some rust.	20 K. 3, 4. First-rate condition; coating could be peeled off with a knife when first taken from the water; afterward hardened again.
30 K. 5, 6. Tough coating, no corrosion, some small blisters near the margin where the coating was very thin.	30 Z. 19, 20. First-rate condition, tough and adherent; not easily scraped off when wet.	30 M. 13, 14. No. 13. Poor, many minute rust-spots. No. 14. Better; little rust. Coating tough and good on both where heavy, brittle and poor where thin.	

The sets of plates at the Norfolk Navy Yard and at Lake Cochituate were left untouched until July, 1899, a little more than two years, but those in the New York Yard were in cages which were suspended to a float which was accidentally sunk in July, 1898, and more than half the plates were lost. The remainder, including part of the 1896 plates just mentioned, were taken out July 21, 1898, after an immersion of exactly thirteen months. Besides this loss, one cage or frame containing twenty-five plates—Nos. 326–350—was lost at Norfolk by the rusting away of the heavy galvanized iron chains which suspended it, and the loss of these plates causes vacant places in the table, so that, in order to save space, it has been thought well to put the descriptions of the

STEEL PLATES. 1896 TEST.

White Lead.	Miscellaneous.	Miscellaneous.
8 M. 17, 18. Poor; coating badly decomposed, the action taking place from the outer surface. Not much corrosion. No. 18 much better than No. 17.	31, 32, 33, 34. Durable Metal Coating. Nos. 31 and 33 all right except some blisters where the coating was thin. Nos. 32 and 34 not so good, more blisters. Coating could be scraped off while wet.	Oil. 40. Red lead in linseed-oil. A good many small rust-spots, but no general corrosion. Coating considerably decomposed; could be scraped off with difficulty. Condition fair.
	35, 36, 37, 38. Sabin Pipe Coating. All perfect.	20 K. 25, 26. Flamingo red in 20 K. Bad condition, many rust-spots.
20 K. 1, 2. No. 1. Good, first-rate condition. No. 2. Good, but some small marginal blisters.		20 K. 27, 28. Ultramarine in 20 K. Not good; many small blisters, not much rust.
	Japan. 39. Ivory-black ground in japan. Very bad; rusty all over.	20 K. 29, 30. Chromium oxide in 20 K. Poor; very many small rust-spots.

aluminum and the 1896 plates in these otherwise vacant spaces. If the reader will bear this in mind, little trouble will be found in following out the plan of the table, the discrepancies of which are caused by accidental losses of plates. No plates were lost in the Lake Cochituate set. The cages, or frames, in which the plates were held were suspended in the Navy Yard by chains about six feet below the surface of the water in such a position that the plates were horizontal. Barnacles and other marine organisms attach themselves to the under side of the plates and by suspending the plates so that they were horizontal, we had practically a double test, one of the lower sides covered with marine growth and another of the upper sides which were practically clear.

There was no considerable deposit of silt on the plates. In the two years' exposure in the Norfolk Yard the action of these organisms was so severe as to destroy the coatings on the under sides of all the plates with the exception of those coated with the "Sabin Pipe Coating," which was not affected, although oysters 4½ ins. in length were found growing on it. When these were removed the coating was found to be intact. But with this exception it should be remembered in looking over the table that only one side of the plates in the Norfolk set is described, the coatings on the other side being uniformly destroyed, while in the New York and Lake Cochituate sets both sides of the plates are included in the description.

The cages containing the plates which were put in Lake Cochituate were laid on the bottom, which was hard and smooth, about 20 feet below the surface. The cages, or frames, naturally laid on their sides, so that the plates were vertical. This made no difference, because fresh-water organisms are rare and they did not attack the plates.

In this triplicate test the general scheme was to apply to a set of four plates a set of three varnishes containing respectively 20, 30, and 40 gallons of oil per 100 lbs. of resin, and raw linseed-oil. Then for another set of four plates, these same liquids were mixed by grinding with white zinc; another set of four was prepared with white lead; another set with ultramarine blue; another with graphite, and so on. This ought to show whether one pigment is better than another and which vehicle is the best. Besides these, plates were painted with pure red lead in pure linseed-oil, with two mixtures of red lead and white zinc, with purple oxide of iron (crocus), in oil, and with "Prince's Metallic" oxide of iron, which is a very well-known pigment consisting of iron oxide mixed with various silicates in oil.

Besides these coatings of known composition, two popular and widely known proprietary paints, the Eureka paint and the graphite paint made by the Detroit Graphite Manufacturing Company, were tried. The oil and proprietary paints were presumed to afford a sort of standard by which the other coatings could be judged.

The coating material described in the table as "Spar" is one of the well-known class of spar varnishes used for exterior and marine work, and the kind used was made by Edward Smith & Company. The "I. X. L. No. 2" is a well-known interior varnish. The substance indicated by the letters "D. M. C." is Edward Smith & Company's Durable Metal Coating, and "S. P. C." is Sabin Pipe Coating, the same as in the former test. "Parahydric" is a coating similar to Durable Metal Coating, but containing less oil, which has been used in painting the interior of water-pipes and for steel in interior construction. "Keystone" is a well-known pigment, probably ground slate, and was used to furnish a pigment composed of silicates for comparison. The iron oxide used is the purest commercial sesquinoxide of iron, containing over 95 per cent. oxide of iron. The purple oxide of iron is oxide which has been subjected to prolonged heating and is supposed to be completely anhydrous. The "iron oxide in shellac" mixture was prepared from a formula furnished by Naval Constructor Bowles. The shellac is pure "D. C." shellac in grain alcohol. The paints known as Rahtjen's, McInnes', and Holtzapfel are anti-corrosive and anti-fouling ships'-bottom paints and were furnished and applied by the New York Navy Yard.

All the paints, except those coated with the Sabin Pipe Coating, which had two coats, received three full coats, well dried between coats. The red-lead paint used weighed about 35 lbs. to the gallon and was put in with the plate in a horizontal position, on the upper side of the plate. After the paint had set, the plate was turned over and the other side was painted. The red lead was in this way more perfectly applied than it probably can ever be in actual work. The nomenclature and abbreviations in the following table are the same as heretofore, with the following additions:

Um. Blue = Ultramarine Blue·
W. Z. = White Zinc;
W. L. = White Lead;
A. = Pure Aluminum;
A. A. = Aluminum Alloy, 95 per cent.

Lake Cochituate, Boston.	401–20 K. No rust except where damaged along edges; many very small blisters.	404–20 M. Much rust; coating much injured.	407–20 Z. Not much corrosion, but coating about destroyed.
	402–30 K. Like 401, not quite so good.	405–30 M. Worse than 404; coating nearly destroyed.	408–30 Z. Like 407, but considerably better.
	403–40 K. Like 401.	406–40 M. Not quite so bad as 405.	409–Spar. Like 408, but perhaps a little better.
Navy Yard, Norfolk, Va.	301–20 K. 301 to 310, coatings not destroyed; all considerably injured; blistered in small spots; no considerable corrosion; 301 worst; 306 and 309 best; 307–8 not bad.	304–20 M.	307–20 Z.
	302–30 K.	305–30 M.	308–30 Z.
	303–40 K.	306–40 M.	309–Spar.
Navy Yard, New York.	1 (1896)–W. L. in 20 K. Some rust along edges; otherwise in good condition.	16 (1896)–W. Z. in 20 M. One-fifth of one side rusted; all the rest in good condition.	47 (1896)–Spar. Coating firm and good; very little rust.
	2 (1896)–W. L. in 20 K. Like 1.	18 (1896)–W. L. in 8 M. Paint hard and firm; in good condition.	35 (1896)–S. P. C. A little corrosion near the edges; otherwise all right.
		20 (1896)–W. Z. in 30 Z. Good. No blisters; no rust.	113 (1896)–S. P. C. Two small blisters; otherwise good.
		22 (1896)–W. Z. in 20 Z. Good. Some corrosion along edges.	

410–I. X. L. No. 2. About like 407.	413–D. M. C. Good, except where broken and injured along edges.	417–Parahydric. Numerous isolated rust spots about ¼ in. diameter; coating otherwise good.	Lake Cochituate, Boston.
411–Shellac. Very excellent condition.	414–D. M. C. Like 413.	418–Parahydric. Like 417.	
412–Raw oil. Surface generally corroded; many tubercles.	415–D. M. C. Like 413.	419–Parahydric. Like 417.	
	416–D. M. C. Like 413.	420–Parahydric. Like 417.	
310–I. X. L. No. 2.	313–D. M. C. Many small blisters, in outer coat chiefly; very little corrosion.	317–Parahydric. Coating all on; no blisters.	Navy Yard, Norfolk, Va.
311–Shellac. Coating practically gone; badly rusted.	314–D. M. C. Like 313.	318–Parahydric. Like 317.	
312–Raw oil. Coating destroyed; very badly rusted.	315–D. M. C. Like 313.	319–Parahydric. Like 317.	
	316–D. M. C. Like 313.	320–Parahydric. Like 317.	
124 (1896)–Spar, one side baked. Very few small blisters, otherwise perfectly good.	105 (1896)–Chromium oxide in 20 K., one side baked. A few blisters; otherwise in excellent condition.		Navy Yard, New York.
104 (1896)–W. Z. in 20 K., one side baked. Like 124.			
122 (1896)–W. Z. in 20 K., one side baked. Like 122.			

Lake Cochituate, Boston.	421–S. P. C. Perfect, except where coating is in one or two places broken at edge with corrosion.	425–W. Z. in 20 K. Half the surface, along the edges, blistered, with rust underneath.	428–W. Z. in 20 M. Outer layer of coating nearly destroyed; under-coat good.
	422–S. P. C. Like 421.	426–W. Z. in 30 K. Much better than 425; some blisters; little corrosion.	429–W. Z. in 30 M. A few slight rust-spots; outer coat blistered.
	423–S. P. C. Like 421.	427–W. Z. in 40 K. Good condition; some blisters in outer layer of coating; no rust.	430–W. Z. in 40 M. About one-fifth rusted; thin rust. Blistered; outer coat chiefly.
	424–S. P. C. Like 421.		
Navy Yard, Norfolk, Va.	321–S. P. C. Perfectly good condition. See note in text.	325–W. Z. in 20 K. Blistered; not very good.	179 A–I. X. L. No. 2. Coating all gone.
	322–S. P. C. Like 321.	176 A–20 K. Three-fourths of coating destroyed; thin rust.	180 A–Spar. Two-thirds of coating gone, but one-third in the middle perfectly good.
	323–S. P. C. Like 321.	177 A–30 K. Like 176.	181 A–D. M. C. One-fifth gone, one-fifth blistered; remainder good.
	324–S. P. C. Like 321.	178 A–40 K. Coating all gone.	182 A–S. P. C. One-tenth gone on one edge; remainder all right.
Navy Yard, New York.			154 A–I. X. L. No. 2. Varnish half gone. Corrosion not deep.
		151 A–20 K. Blistered along edges and a few spots. Varnish firm. Little corrosion.	155 A–Spar. Most of the varnish soft, but some not affected. Not badly corroded.
		152 A–30 K. Much corrosion; some deep. Coating half gone; remainder firm.	157 A–D. M. C. Twenty per cent. blistered around edges. Coating firm; not much corrosion.
		153 A–40 K. Badly corroded; coating nearly all destroyed.	158 A–S. P. C. Excellent. Coating not injured, except by accident in removing from frame.

431–W. Z. in 20 Z. Not much rust; outer coat badly blistered; under coat slightly so.	436–W. Z. in 20 K., baked. Almost perfect; still shows glossy surface of varnish.	439–W. Z. in 20 M., baked. Good; coating brittle in places and shows deterioration.	Lake Cochituate, Boston.
432–W. Z. in 30 Z. Better than 431. Outer coat blistered.	437–W. Z. in 30 K., baked. Like 436.	440–W. Z. in 30 M., baked. A little better than 439	
433–W. Z. in Spar. Like 432.	438–W. Z. in 40 K., baked. Like 436.	441–W. Z. in 40 M., baked. Almost perfect.	
435–W. Z. in Raw Oil. Four-fifths of surface badly rusted; deep corrosion.			
183 A–S. P. C. Perfectly good condition.	187 A–W. Z. in Spar. Like 184.	191 AA–I. X. L. No. 2. Coating all gone.	Navy Yard, Norfolk, Va.
184 A–W. Z. in 30 K. Fine; no rusting nor blistering.	188 AA–20 K. Coating all gone.	192 AA–Spar. Three-quarters gone; like 189.	
185 A–W. Z. in 40 K. Like 184, but discolored.	189 AA–30 K. Three-quarters gone; small patch in the middle all right.	193 AA–Spar. Like 192.	
186 A–W. Z. in 30 Z. Like 184.	190 AA–40 K. Half gone; like 189.	194 AA–D. M. C. One-third badly blistered from edges; remainder good.	
159 A–S. P. C. Like 158 A.	163 A–W. Z. in Spar. Not deeply corroded. Several large blisters; otherwise in good condition.	167 AA–I. X. L. No. 2. Considerable blistering and corrosion. Coating easily scraped off.	Navy Yard, New York.
160 A–W. Z. in 30 K. Upper side perfect; lower side slightly blistered. Coating hard.	164 AA–20 K. Badly corroded; three-fourths of the varnish destroyed.	168 AA–Spar. Like 167, but not badly corroded.	
161 A–W. Z. in 40 K. No blisters; otherwise like 160 A.	165 AA–30 K. Like 164 AA.		
162 A–W. Z. in 30 Z. Like 161 A.	166 AA–40 K. Badly blistered, but not badly corroded. Coating on one side firm; on the other soft.	169 AA–D. M. C. Many blisters; very little corrosion; coating generally firm.	

Lake Cochituate, Boston.	442–W. Z. in 20 Z., baked. Nearly perfect.	445–W. L. in 20 K. Very little corrosion. Some superficial blisters.	449–Um. Blue in 20 K. Considerable rust; not deep; paint practically destroyed.
	443–W. Z. in 30 Z. baked. Excellent; no rust; blisters superficial and few.	446–W. L. in 30 K. Good condition; no rust. Some superficial blisters.	450 Um. Blue in 30 K. A little worse than 449.
	444–W. Z. in Spar, baked. Like 443 or better.	447–W. L. in 40 K. Like 446.	451–Um. Blue in 40 K. Worse than 449; deep rust.
		448–W. L. in Raw Oil. Much deep corrosion; about half the plate in good condition.	452–Um. Blue in Raw Oil. Like 451; whole surface rusted.
Navy Yard, Norfolk, Va.	195 AA–W. Z. in 30 K. Good; blistered a little on the edges.	199 AA–S. P. C. Blistered a little from edges; otherwise all right.	
	196 AA–W. Z. in 40 K. Fine, but discolored; like 185.	200 AA–S. P. C. Like 199.	
	197 AA–W. Z. in 30 Z. Fine, but blistered a little along the edges.		351–Um. Blue in 40 K. Nearly all gone.
	198 AA–W. Z. in Spar. Like 197.		352–Um. Blue in Raw Oil. Coating all gone; very badly rusted.
Navy Yard, New York.	170 AA–W. Z. in 30 K. Very little corrosion. Blisters amount to 1 per cent. Coating good.	174 AA–S. P. C. In perfectly good condition.	
	171 AA–W. Z. in 40 K. Good, but not equal to 170 AA.	175 AA–S. P. C. Like 174.	
	172 AA–W. Z. in 30 Z. No corrosion; no blisters; excellent condition.		251–Um. Blue in 40 K. Very many small blisters; very little corrosion.
	173 AA–W. Z. in Spar. About like 172.		252–Um. Blue in Raw Oil. Uniformly corroded; coating all gone.

453–Graphite in 20 K. Very good; some small blisters.	457–Keystone in 20 K. Good condition; no rust; some small blisters.	461–Iron Oxide in 20 K. Very little rust; small blisters in outer coat.	Lake Cochituate, Boston.
454–Graphite in 30 K. Like 453.	458–Keystone in 30 K. Like 457.	462–Iron Oxide in 30 K. Better than 461; no rust.	
455–Graphite in 40 K. Like 453.	459–Keystone in 40 K. A little rust; many small superficial blisters.	463–Iron Oxide in 40 K. Like 462.	
456–Graphite in Raw Oil. Deeply and generally rusted; about one-tenth of the paint still good.	460–Keystone in Raw Oil. Badly and deeply rusted; patches of paint still good.	464–Iron Oxide in Raw Oil. Corrosion deep and general; paint all gone.	
353–Graphite in 20 K. Three-quarters gone; much rust.	357–Keystone in 20 K. Coating blistered and one-quarter gone.	361–Iron Oxide in 20 K. Pretty good condition; a few blisters.	Navy Yard, Norfolk, Va.
354–Graphite in 30 K. Half gone; much rust.	358–Keystone in 30 K. Blistered, but not destroyed.	362–Iron Oxide in 30 K. Not quite as good as 361.	
355–Graphite in 40 K. One-quarter gone.	359–Keystone in 40 K. Blistered, but not in bad condition.	363–Iron Oxide in 40 K. Like 361.	
356–Graphite in Raw Oil. Nearly all gone; badly rusted.	360–Keystone in Raw Oil. All gone; badly rusted.	364–Iron Oxide in Raw Oil. Like 360.	
253–Graphite in 20 K. A few blisters; very little corrosion.	257–Keystone in 20 K. No corrosion; numerous very small blisters.	261–Iron Oxide in 20 K. Blistered, but not very badly. Not much corrosion.	Navy Yard, New York.
254–Graphite in 30 K. Like 253.	258–Keystone in 30 K. Like 257.	262–Iron Oxide in 30 K. Like 261. Not deeply rusted.	
255–Graphitein 40 K. No corrosion. Paint in good condition. Numerous very small blisters.	259–Keystone in 40 K. Like 257.	263–Iron Oxide in 40 K. Like 262.	
256–Graphite in Raw Oil. Uniformly corroded; coating all gone.	260–Keystone in Raw Oil. Coating destroyed and plate badly corroded.	264–Iron Oxide in Raw Oil. Like 260.	

Lake Cochituate, Boston.	465–Red Lead in Raw Oil. Paint still tough; looks well. Blisters from the bottom with slight corrosion beneath.	469–Eureka Paint. General corrosion; paint entirely destroyed.	
		470–Detroit Graphite. Like 469; paint nearly all destroyed.	475–International Holtzapfel. Like 469.
	467–Prince's Metallic in Raw Oil. About one-quarter deeply rusted; paint practically all gone.	472–Iron Oxide in Shellac Mixture. Good condition; about 2 per cent. rusted.	477–Red Lead and W. Z. in Raw Oil. Many deep rust-spots; about 5 per cent.; remainder good.
	468–Purple Oxide in Raw Oil. Like 467.		478–Red Lead and W. Z. in Raw Oil. Like 477. Not nearly as good as 465.
Navy Yard, Norfolk, Va.	365–Red Lead in Raw Oil. Coating destroyed; plate badly rusted.	369–Eureka Paint. Like 365.	374–McInnes' Paint. Like 372.
		370–Detroit Graphite. Like 365.	375–International Holtzapfel. Like 365.
	367–Prince's Metallic in Raw Oil. Like 365.	372–Iron Oxide in Shellac Mixture. Paint destroyed; general but not deep corrosion.	377–Red Lead and W. Z. in Raw Oil. Like 365.
	368–Purple Oxide in Raw Oil. Like 365.	373–Rahtjen's Paint. Like 365.	378–Red Lead and W. Z. in Raw Oil. Like 365.
Navy Yard, New York.	265–Red Lead in Raw Oil. Coating badly destroyed. Considerable corrosion.	269–Eureka Paint. Like 260.	274–McInnes' Paint. In good condition; no barnacles.
		270–Detroit Graphite. Like 260.	275–International Holtzapfel. Paint badly gone; much corrosion; many small barnacles.
	267–Prince's Metallic in Raw Oil. Like 260.	272–Iron Oxide in Shellac Mixture. A few blisters; otherwise in good condition.	277–Red Lead and W. Z. in Raw Oil. Coating thin; gone in many places; considerable corrosion.
	268–Purple Oxide in Raw Oil. Like 260.	273–Rahtjen's Paint. Paint badly gone; considerable rusting. Many small barnacles.	278–Red Lead and W. Z. in Raw Oil. Like 277.

481–20 K., baked. Practically perfect; coating still glossy.	484–30 M., baked. Several deep spots of rust, coating badly blistered.	487–I. X. L. No. 2, baked. Like 481.	Lake Cochituate Boston.
482–30 K., baked. Like 481.	485–30 Z., baked. Like 481.	488–Raw Oil, baked. Badly and deeply rusted. Two-fifths of the surface good.	
483–40 K., baked. Like 481.	486–Spar, baked. Like 481.	489–D. M. C., baked. Fine; a few small blisters in the outer coat.	
381–20 K., baked. Half of the coating destroyed; the rest good. Not much rust.	384–30 M., baked. Like 382.	387–I. X. L. No. 2, baked. Like 386.	Navy Yard, Norfolk, Va.
382–30 K., baked. Four-fifths destroyed; very little rust.	385–30 Z., baked. Like 382.	388–Raw Oil, baked. All gone; rusted.	
383–40 K., baked. Like 382.	386–Spar, baked. Nearly all gone; little rust.	389–D. M. C., baked. Three-quarters gone; remainder good; very little rust.	
281–20 K., baked. Plate thinly rusted along the edges.	284–30 M., baked. Many small and some medium-sized blisters. Not badly rusted.	287–I. X. L. No. 2, baked. Not much corrosion; very small blisters.	Navy Yard, New York.
282–30 K., baked. Small blisters, with thin rust beneath, over most of the plate.	285–30 Z., baked. Good condition. Very little rusting. Very small blisters.	288–Raw Oil, baked. Badly corroded. Coating destroyed.	
283–40 K., baked. Very small blisters; not much rust.	286–Spar, baked. Coating badly destroyed; much corrosion.	289–D. M. C., baked. Very many small blisters. Not very much corrosion.	

A careful study of the plates after their removal from the water showed that it is generally true of all the better class of coatings that corrosion begins at the edge of the plate. In the case of aluminum plates it seemed evident to the writer that some of these coatings, notably the spar varnish and the "Durable Metal Coating," had been gradually thrown off by corrosion creeping from the edge, probably from some mechanical injury under the varnish, a patch of which remained uninjured, elastic, and apparently without deterioration on the middle of the plate. This fact should not be lost sight of in considering this matter, and is one of the points shown by an inspection of the plates, but not brought out easily in a description. As a rule, with the less effective coatings, they begin to deteriorate from the surface, which becomes rough; then little blisters appear which are caused by the separation of the last coat from those beneath; finally the undercoat blisters, in which case it is found almost invariably that rust has formed under the blister. If, however, the coating is porous, and this seems to be the case with the ordinary oil paints, the water reaches the metal and causes rust. This throws off the paint-film, and the corrosion spreads rapidly in this way.

These tests undoubtedly seem to prove, and I think they do prove, that varnish forms a much more continuous (less porous) film than oil, which agrees with all that has heretofore been said of the nature of varnish-films. In all these tests the oil paints have failed without exception, while the corresponding varnish paints remained in most cases in good condition. The character of the pigment does not seem to have much influence. All the oil-paint samples were so badly rusted that differentiation among them was impossible. It may be that an earlier inspection would have shown differences, but as it was, the appearance of all these plates when removed from the water was so similar that it seems unlikely, and certainly the varnish paints did not show any great difference in the matter of the pigments, except that white zinc seemed to be somewhat the best. The iron oxides, graphites, and pulverized slate were all alike. The red lead, in the Lake Cochituate and New York sets, was far better than any of the oil paints. The mixtures of red lead and white zinc were markedly inferior to red lead alone. In the Norfolk test, which was much more severe, the red lead had finally been quite destroyed. Deterioration in the case of red lead always seems to start from centres.* In the Lake Cochituate set the red lead was in pretty good condition, but as it showed numerous rust-spots, without superficial blisters, but all defects running through to the metal, it probably would not have lasted more than a year or so longer. Most of the varnish paints were much better than the red lead. A study of the varnishes applied without pigment seems to show that in the fresh-water exposure the process of baking was, on the whole, of advantage, but not greatly so. In the salt water the unbaked varnishes were better than the same varnishes baked. This agrees with the results of the 1896 tests. The Manila varnishes are clearly inferior to the Kauri and Zanzibar. The "Durable Metal Coating" was best of all. This is doubtless due, in a large degree, to the fact that this varnish, which is intended especially for the protection of structural steel, is made with a heavy body and the film is of greater thickness than is the case with varnishes intended for woodwork. Its composition has also been very carefully studied and designed to secure great durability, which is of much less importance than other qualities in ordinary varnishes.

By far the best results, however, with the exceptions to be hereafter noted, were obtained from the best of the enamel paints. Here, also, the Manila varnishes were decidedly inferior, and in my opinion these should be excluded hereafter from any such tests, although they make a very good showing on wood. In the enamel or varnish paints, those made with the more elastic

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* This may have been caused by coarse particles of red lead which reached through the film, and thus formed weak spots. It must be remembered that this painting was done in 1897, at a time when little consideration was given to the fineness or chemical composition of red lead, which was judged chiefly by its color; and that the red lead used was not the finer grade known as "painters' red lead," but was such as was bought for making driers by the varnish-makers. It is now known that such red lead is not adapted for use as a pigment, and it is remarkable that it made as good a showing as it did.

varnishes (those containing the most oil) were decidedly the better. The extreme durability of these is well shown by the 1896 plates. These were first exposed to the air two or three months, then they were in the sea-water six months, then exposed to the air nearly a year, then under water thirteen months, and have since been exposed to the air five years, making a total of eight years, and they are still, to all intents, perfect. It is true that the air exposures have been indoors, but most paints rapidly lose their coherence when, after a prolonged immersion, they are exposed to the air. Two years' continuous submersion in fresh water has not injured some of these enamels, and two years in the excessively severe exposure at the Norfolk Navy Yard has left several of them in good condition, a few being practically uninjured. Undoubtedly the most obvious and conspicuous and the most instructive part is the total and absolutely universal failure of linseed-oil films, either alone or mixed with any of the numerous pigments which were tried, while the corresponding varnishes and enamel paints made with the same pigments were in fair to good condition. It is not to be forgotten, however, that the only varnishes used in this test were those having 20, 30, and 40 gallons of oil to the unit 100 lbs. of resin. The 30- and 40-gallon varnishes may be regarded as special structural varnishes, being more elastic and less brilliant and hard than are acceptable for any ordinary commercial work; the 20-gallon varnishes, which made the poorest showing, being the only really commercial varnishes in these tests, except the spar, which is intermediate between the twenties and thirties, made especially for marine use, and the "Durable Metal Coating," a highly elastic special varnish made exclusively for structural metal protection. The relatively poor showing made in 1896 by the 8- and 12-gallon varnishes sufficiently proves that the best ordinary varnishes, though made with the highest skill and of the most expensive materials, are unfit for prolonged and severe exposures. The results which are likely to be obtained from the use of common cheap varnishes may safely be left to the imagination of the reader. The great durability of the varnish and enamel films in these tests confirms strikingly the opinion long held by the writer that properly made varnish-films are much more impervious and resistant than any others. The exceptional cases to be noted are:

First. The "Sabin Coating," a baked enamel, which is so much superior to the others as to form a class by itself, and

Second. The extraordinary showing made by pure shellac varnish in the Lake Cochituate test.

Shellac Varnish in Fresh Water.—Shellac varnish is simply a solution of shellac resin, which is chemically an acid substance, in alcohol. There are many grades of shellac; the one used was what has for many years been known as "D.C." Orange Shellac, and it was dissolved in pure 97 per cent. grain (ethylic) alcohol. Being an acid substance, it is attacked readily by the ammonia in the atmosphere. It is removed easily by soap and water. It has never been considered a durable varnish as ordinarily used on woodwork, and it does not stand at all in the sea-water tests, but two years' exposure under 20 feet of fresh water does not seem to have injured it sensibly. This may be a serious matter, for while in this regard it is no better than some other varnishes which cost less money, shellac varnish has some important and exceedingly desirable qualities which no other varnish has. For example, occasionally we encounter the problem of repainting a large section of large water-pipe which can be spared for use only a few days. The interior of this pipe is damp. The best that can be done with it is to get out most of the visible water, but the cold surface of the metal will always be damp. No ordinary varnish will stick to such a surface, and corrosion will probably be set up at once. No oleo-resinous varnish of ordinary character, of sufficient durability to be worth putting on, will dry in the limited time at our disposal. But shellac is dissolved in a vehicle which has an intense affinity for water, and a thin film of dew will be instantly absorbed and removed by the evaporation of the slightly diluted alcohol; and shellac, if applied in a thin coat, dries with the greatest rapidity. Three coats may be applied in eight to twelve hours. There is no unpleasant or dangerous odor, though ventilation should be secured both on account of the risk of fire and because working in an atmosphere of alcoholic vapor produces intoxication. It certainly seems from this test as though we should be justified in using shellac varnish in such a case. It is expensive, of course, and it is almost certain that the cheaper grades, which are found in ordinary use to be very much inferior in durability, would not be so efficient. In any case, it would not be necessary to use it when the conditions are such that some equally good (or better) but slower-drying coating can be used.

During the years which have elapsed since these tests were made the writer has given considerable attention to the subject of ships'-bottom paints, which are all made with a quick-drying spirit varnish as the vehicle for the first coat, and there is no doubt that these varnishes act as shellac acted in this test. Of course none of these have as much durability, because they are in sea-water instead of fresh water, but they are, like shellac, coatings which will not stand weather exposures for even a few months, but when put under water immediately after their application they last six to twelve months. This is well-established practice, known to all who have the care of ships, and strongly confirms the opinion just expressed, that the use of shellac in such a case as has been described could not be regarded as an unwarranted experiment.

It is sometimes objected to these submarine tests that they are of value only as regards the same conditions, and there is some justice in such a criticism, but it is much weakened by the obvious fact that there is a practical agreement between the fresh-water and the sea-water tests. The latter were most severe, but in most cases the difference has been one of degree only. And in the rather large experience of the writer and his associates these tests seem to agree in general with aerial exposures, reasonable exception being made in the case of coatings intended expressly for marine or for aerial use. The zinc and lead enamels make a rather better relative showing under water than in weather exposures, although excellent for the latter.

Laboratory Tests not Decisive.—Exposure tests, such as these, are of much more importance than laboratory tests. The manufacturers of paints and varnishes, some of whom are probably the best experts in this matter, never depend on any but an exposure test. It is by no means impossible that rapid laboratory tests may yet be devised, but such crude ones as have been so far proposed are in most cases of little value. Such a test, for example, is that with caustic alkali. This is a substance unknown in nature, and no good paint will stand it, while a perfectly worthless paint may be made which will stand it very well. A nitric-acid test is of the same sort. It will simply burn up any organic substance, and some of the best linseed-oil paints yield to it most readily. It would hardly be regarded as a fair test of the comparative health of a dozen animals to administer to each of them a couple of ounces of nitric acid and watch to see which lived longest, yet probably each could take a few drops of it per day without inconvenience. This is about what many of the so-called paint tests amount to. Some laboratory tests are of some value, but none is conclusive. A heat test is at present popular. The painted sample is heated to perhaps 400° Fahr. for a time and its subsequent appearance studied, on the supposition that the rapidly increased oxidation at high temperatures may bring about the same changes which will occur at ordinary temperatures slowly. This is plausible and there is something in it, but it is applicable only to such coatings as are intended to stand a high heat because other changes than oxidation are involved. It has already been observed that we know of instances where oak beams have been exposed to the air for a thousand years without injury, while two hours in an oven at 400° Fahr. will begin the decomposition of wood. Now the ratio between two hours and a thousand years is as one to over four millions, which shows the utter absurdity of any such test if applied to miscellaneous coatings. The preceding tables show the same thing in a different way. Some of the coatings were improved by baking, others were injured. Those which were designed by the makers to be baked were bettered, and those which were planned to give the best results without baking were injured. To make a suitable compound to be applied by baking at a high temperature which will show mechanical toughness, elasticity, and hardness, combined with chemical inertness and permanence in the finished product, is the most difficult thing yet attempted in this kind of work. In such a compound the process of baking effects a chemical union among its constituents as well as with the atmospheric oxygen. In what has been said about the varnishes and enamel paints employed in the foregoing tests, the subject of the use of these compounds for the protection of steel is tolerably well covered. These experiments are, of course, greatly amplified and supplemented by the experience of the author in the actual protection of structures in great variety, leading to the following general conclusions:

Ordinary varnishes are made to combine two functions; one is the protection of the surface to which they are applied, the other is to provide it with a hard and brilliant coating which serves for ornament. To secure the latter it is necessary to have the resin constitute about one-third to three-elevenths of the weight of the dry film; these proportions correspond to varnishes made with from 20 to 26 gals. of oil to 100 lbs. of unmelted resin. Varnishes made for interior use have sufficient durability even if the proportion of resin exceeds this, and as the resinous ingredient increases, so does the brilliancy of the varnished surface, and polishing-varnishes seldom have more than about 60 lbs., say 8 gals., of oil to 100 lbs. of resin, or the film will contain considerably more than half its weight of resin, after allowing for the loss of the latter in melting. Such is the character of commercial varnishes; but when we have reached the maximum of 26 gals. of oil we have only begun to approach the amount necessary for the highest degree of durability without adornment, which is sought in the protection of metal from corrosion.

Varnish for Steel Structures.—For this purpose a varnish of 26 gals. of oil to the 100 lbs. of resin may perhaps answer, but we know that 30 gals. is better and for many places a 40-gal.

varnish is better than a 30. The broad statement may then be made that varnishes made for any ordinary use on wood are not suitable, not sufficiently elastic, for use on structural steel; and conversely, that a varnish soft and elastic enough to be right for the latter purpose has not enough hardness and lustre for general use. It will, of course, be much harder and more lustrous than an oil-film, because oil is the softening ingredient in varnish, and the added resin imparts hardness and brilliancy and smoothness of surface; and it also acts, as has been explained, as a flux, promoting in an extraordinary degree the uniform and continuous oxidation of the compound (or the oil which it contains) and thus producing a continuous and non-porous film. A 40-gal. varnish contains in the dry film resin in the proportion of 1 part to 4 parts of oil; this may seem to the unpractised reader, or perhaps even to the experienced user of hard varnishes, not enough to have much effect, but it is. Probably almost every practising chemist has some time tried to dissolve an old gold pen in nitric acid; the base metal, chiefly copper and zinc, alloyed with the gold not only makes the article cheaper, but adds to its rigidity and elasticity, and frequently amounts to two-thirds of the weight; and this is easily soluble in acid, in which the gold is insoluble; but every one who has tried it has been astonished to see how much the small amount of gold protects the large amount of base metal, and how long a time it takes to dissolve out the latter. It is exactly so with a varnish: the effect of the resinous ingredient is out of all proportion to the amount present. It is quite likely that this proportion of 4 parts of oil to 1 of the melted resin is as great as can be made to enter into true combination and that any further increase only dilutes the varnish with oil; certainly the making of a really good varnish with so much oil as this is a matter of difficulty; in fact, as a general rule, the less oil there is in a varnish the easier it is to make, and a 10-gal. varnish, for example, diluted with 10 gals. of oil is not in the least like a 20-gal. varnish. The oil and resin must be combined in the making, and no varnish can have a high degree of durability unless its ingredients are thoroughly united. It is, moreover, desirable, indeed indispensable, for reasons already explained, that it should contain a minimum amount of "drier," or lead and manganese compounds. There are structures which, on account of their location and use, require a varnish having more than the minimum degree of hardness and smoothness in the coating. Where the proportion of oil must fall as low as thirty gallons, perhaps sometimes even less, such things are best known by experience and observation. The making of varnishes for such work is not a job for the inexperienced amateur, but for the scientific investigator, who may well be, in the best sense, an amateur varnish-maker, it offers a large and important field for practical and theoretical research.

The most serious objection to the use of varnish as a protective coating is the thinness of the film, which, although greater than that of an oil-film, is less than that of a good oil paint, and is usually too thin for permanent service. This may be remedied by making the varnish heavier in body or more viscous, and it may be thus made so thick that any desired thickness of film can be obtained. If in making varnish the cooking be stopped as soon as the oil and resin have combined enough so that they will not separate on cooling, the product, if it contains a large proportion of oil, will be sufficiently fluid for use with a comparatively small proportion of spirits of turpentine; it thus contains a large percentage of non-volatile ingredients, which in itself is of advantage; but in such a varnish the oil has not become sufficiently united with the resin, and its durability will not be as great as that of a well-cooked varnish.

In 1914 Professor A. W. Muckenfuss, in a paper read before the A. S. T. M., described experiments showing the permeability of oil, paint and varnish films, which were formed on porous or non-continuous surfaces, and exposed to vapor of water; the vapor which passed through was collected and weighed. In all cases some water vapor was transmitted. The writer submitted the following as an explanation; as it has been approved as possible by various physicists of good standing, it is reproduced here, from the proceedings of the society, as a tentative theory of protection by films.

Professor Muckenfuss has shown much ingenuity, skill and patience in the tests he has described, and the results are of much interest. It appears that all the films he used proved to be permeable to water vapor. This suggested some reflections to the writer, and in conference with Mr. Muckenfuss the latter expressed the opinion that they might prove suggestive to the other students of the subject; hence the following brief observations: During the years 1895–1898, the writer was carrying on a series of tests of oil and varnish paints and varnishes, on steel and aluminum plates, both in fresh and sea-water. It is well known that sea-water readily attacks aluminum, hence tests of protective films on that metal in sea-water are conclusive one way or the other. Some of these films, in particular some of the varnish coatings, afforded practically complete protection both to steel and aluminum. It is worthy of mention that some of these varnishes, containing two to three times as much linseed oil as resinous matter, appeared soft and somewhat like very thin leather thoroughly watersoaked; they could be peeled up from the metal support in long strips, yet the underlying metal was not rusted at all, and when allowed to dry the films became hard again and regained, in part, their natural gloss or lustre. There is no question as to the facts, because they were inspected on removal from the water by the U. S. Naval constructors, by several well-known engineers, and by representatives of the Engineering News and Engineering Record, who had been invited to be present; also the plates were subsequently exhibited before the American Society of Civil Engineers, the Engineers Club of Philadelphia and the Boston Society of Engineers. Now, if these films were permeable, why did the plates not rust, especially the aluminum ones? The same is true of the plates of the Havre de Grace test. After five years' exposure to the weather nineteen of these plates, one of each kind of paint, were removed, inspected, the paints cleaned off with caustic soda, and in most cases the steel was exactly as free from rust as when it was first painted. Why did not these rust? There is no question about the facts; and no one doubts, on the other hand, that Mr. Muckenfuss did really find that similar films allow water vapor to pass through rather easily. Who will explain these apparently contradictory facts? Not the writer; but attention may be directed to the common experiments on osmosis, a subject of physical chemistry. The chemist has found that there is a class of substances, usually spoken of as films, which are semi-permeable; they will allow certain solvents, such as pure water, to pass through, but will not admit the passage of substances in solution in these solvents; so in a manner, they afford a way of separating the dissolved matter from the solvent. May it be possible that films which have proved useful for protective coatings, while they are permeable to absolutely pure water, which does not cause corrosion, do not admit the passage of ionized substances which are active in that regard? It is a fact that these semi-permeable films, as used in chemical experiments, do not allow ionized matter to pass; they are never spoken of as being porous, their permeability being restricted to certain fluids, and in fact they are artificially made on a porous foundation as a support. The water which, in Mr. Muckenfuss' experiments, passed (in vapor) through the films, may have been absolutely chemically pure water. It may be that a film which has value as a protective on metal is entirely free from porosity, having no holes in it except such as are due to mechanical imperfections; that it is, in fact, a semi-permeable membrane; and that its usefulness terminates when, either from chemical or mechanical action, or both, it loses its mechanical continuity and admits ordinary impure water and air.

A practical difficulty which perhaps more than any other one thing prevents the extensive use of varnish and varnish paints on steel structures is the fact that such materials do not brush out freely, and are much affected in this respect by low temperatures, which increases the labor and requires more skill than the use of oil paints. Such paints and varnishes have low spreading power, covering usually about 350 sq. ft. per gallon; ordinary bridge-painters dislike them because they require more labor and the workman does not have as much surface to show for his day's work as usual. All this is a matter of cost, in reality, and if the results warrant it may be overlooked.

Enamel Paints.—It has already been said that pigments can be used in varnish just as in oil, and the varnish paints, or enamels, as they are sometimes called, are, if made of proper materials, highly suitable for painting structural metal, especially bridges. Some of these varnish paints, which naturally exceed in thickness and hardness of film the varnishes themselves, while they retain all their elasticity, are coatings of great beauty and permanence. The cost of properly applying a protective coating to structural metal is often as great as the cost of the paint or varnish itself and not infrequently much more.

There are places where it costs $4 to $6 for labor to apply a gallon of varnish paint to a cleaned surface, and it is not uncommon to spend $3 to $6 in cleaning the surface to which a gallon is to be applied.

True Economy in Painting.—An increasing number of bridges are now cleaned either wholly or in part with the sand-blast, and this probably is not done at present for less than 2 cents per square foot. A gallon of paint will cover at least 300 sq. ft.; red lead, as explained elsewhere, covers more than twice this surface, and carbon and iron oxide paints are sometimes, but unwisely, made so thin as to cover 550 to 750 sq. ft.; but good bridge paints other than red lead usually cover 300 to 400 sq. ft., and a good enamel paint, which has low spreading power, ought to cover 300. The cost of sand-blasting this would be $6. Actual costs which have been shown the writer by several maintenance engineers indicate the cost of scraping and wire-brushing to be from half a cent to two cents per square foot.

As to the cost of labor for applying paint, in general it is probable that a gallon per day per man is a fair estimate. A very easy working paint on rather plain and flat smooth new surface may be applied at double this rate; and on rough and difficultly accessible jobs half this amount will be found enough. At the time of writing painters get from 40 to 70 cents per hour; the latter figure is exceeded in at least one large city. At the minimum rate, 40 cents per hour for eight hours is $3.20 for labor for applying a gallon of paint, and $4 is nearer current practice. To this must often be added something for scaffolding, but not always. As to cost of paint, two or three railway companies have installed mills, etc., and make their own paint; invariably these people manipulate their book-keeping so as to show a cost lower than that which any manufacturer can figure; moreover, in every case with which I am acquainted (and I think I know them all) the paint so made is very poor paint, and is so regarded by all good judges. These paints are variously figured to cost from 65 cents per gallon upward, usually up to about $1; but in the first place they really cost much more, and in the second, they would be dear if they cost nothing. It costs as much to apply a poor paint as a good one, and the labor is what costs.

The cheaper proprietary paints, which are good enough to carry the name of a responsible maker, are sold, as the oil market varies, at from $1.20 to $1.50 per gallon; the really good ones at $1.50 to $2 per gallon. If we assume that a gallon of paint costs $1.50 and covers 400 sq. ft.; that the cost of cleaning is 1 cent or $4 and the labor $4 we have $9.50 for the paint when applied. If a gallon of enamel paint costs $3 and covers 300 sq. ft., the cost for 400 sq. ft. is for paint $4, cleaning $4, labor $5.33, total $13.33. If it lasts four-tenths longer it is as cheap; that is, if the cheap paint lasts three years the higher priced one must last four years and two months. Now, I know of several railroads, including two large ones, whose engineers reckon regularly on repainting, usually from the metal, every three years, using cheap paints; and I have never known of really good varnish or enamel paints which required replacing in five years. I personally know of numerous cases where such paints have lasted sixteen to twenty years; and the chief engineer of one of the largest of our railways has told me of bridges painted with three coats of red lead which lasted twenty years. I know of one such bridge which had red lead painting which lasted sixteen years; and there is one very large and well-known bridge which in over forty years had at first three coats of red lead, and at intervals three more coats altogether, and has been in good condition all the time. There is no use in telling me that there is economy in using a poor paint because its first cost is low.

Too often the selling price per gallon determines the question of the use of a paint or the reverse. Too often the purchasing agent is oblivious to the argument in favor of economy in the end; all he cares for is keeping this year's budget as low as possible, and evidence that five years hence such practice will be proved bad has no effect, because he thinks if he makes a low record this year and next, he will be promoted to a higher position, and then he can afford to forget his mistakes, which some one else will have to shoulder. Not all nor a majority of purchasing agents are like this; but in any class of men a small percentage of such people will throw a shade of discredit and suspicion on the whole class. So, likewise, it is with supply men. The line of least resistance is to give every one what he thinks he wants; but there is no more certain road to ruin. Real progress in manufacturing is in giving the consumer more service for the same money; if this means a lower unit price, well and good; but if it means a higher unit price, also well and good. The cost of paint is not known until the structure is repainted; the cost is the cost per square foot per year; including labor, interest, and everything. So far as the writer's observation goes, a very cheap paint or varnish is not what it is pretended to be; and if this is so, doubt is at once thrown on its whole value. As a general rule, no really first-class goods can be made without skilled labor, and the more skilled labor is used, the greater will be the cost. A thing is not good merely because it is expensive; but if it is a thing which is capable of being made better by skill, then the best of the sort cannot be cheap, and yet is likely to be economical in use.

Spraying-machines.—Paint is usually applied with a brush; but not a little is put on with spraying-machines, which operate with compressed air and spray the paint over the surface. These work well on large flat surfaces, but have not been used much on bridges, because of the difficulty of avoiding waste of paint in directing the spray against narrow members; but spray jets are to be had which throw a very narrow stream. They are used much in freight-car painting; and the writer knows of their successful use in painting the underbodies or gear parts of street cars.

There is difference of opinion as to the comparative merits of machine and brush work. The advantage of the machine is that the spray is carried along in a current of air and so penetrates cracks and recesses which are inaccessible to the brush; and it does not skip anything; the most irregular surface is as well painted as a plain one. It has been used for painting old bridges which had been cleaned of rust by the sand-blast, which latter by cleaning out rust from cracks left them open, and while they could not be reached by a brush the spray filled them in a satisfactory manner. The advantage of the brush is that the paint may be rubbed with more force into the surface, and it commonly believed that a paint well rubbed out is more durable than one less carefully applied.

Recently the spraying-machine has been modified so as to be used in carriage and automobile painting, even varnishing is done with it. It is said to give satisfactory results, and to be more rapid than brushing. The work, in this case, is done under a hood provided with a strong exhaust current of air, so that any floating spray is instantly drawn off. In this way it is made sanitary; and by using paints and varnishes of good flowing quality, and drying the work in a hot room, the surface is all that can be desired. There is much difference in the quality of work done with the brush. In the first place, there are differences in brushes. A cheap or worn-out brush containing not enough bristles does not absorb enough paint. In order to put on a full, flowing coat the brush should be capable of holding enough paint to act as a sort of reservoir, so that the end of the brush which comes in actual contact with the surface will be for a reasonable time amply supplied with paint and will not drag and pull on the surface. With a dense, well-made brush, saturated with paint, the workman can spread and rub out the paint without having it absorbed again by the brush.

Sometimes a skilful house-painter makes a poor job on structural steel work for the reason that he has been accustomed to rub out his paint very thin, so as to make an excessively thin, smooth coat, and one which will dry quickly; whereas, the primary thing in this work is to put on a full, heavy coat, which will afford protection to the metal, and while it is better to be smooth, it is necessary that it should not be thin. House-painters, moreover, find it hard to believe that a slow-drying elastic paint is fit for any use and are possessed with a determination to improve it by the addition of driers. In such a state of affairs about two inspectors are needed to watch each painter.

Influence of the Weather.—It is generally agreed that paint should not be applied in wet or freezing weather, but one side of a bridge is frequently shaded, and its temperature may be less than that of the air, and if the latter is saturated with moisture, or nearly so, the sunny side of the bridge may be dry and in good condition to paint and the shaded side covered with dew. Similarly, bridges often span cool, dark ravines, and sometimes there are only a few hours in the middle of the day when such a bridge is in the best condition to paint. So it appears that besides proper cleaning of the structure and selection of the most suitable paint it is important and sometimes difficult to get the paint put on in the best manner. Unless the metal in a structure can be enclosed so as to keep the air away from it, it is probably desirable to expose it to a free circulation, with the aim of keeping it all as nearly as may be at the same temperature, so that no part of it shall be so shaded or protected as to have its temperature below the dew-point.

It should not be forgotten that strength, though essential, is not the only desirable quality for a bridge. Rigidity is very important and greatly promotes the preservation of the metal, for if the bridge vibrates when a load passes over it, as many highway bridges and some railway bridges do, the joints become loosened, and if wet with rain or snow the water is mechanically worked into the joints, the paint which was put there is broken up and destroyed, and rusting is promoted in a decided manner.

Some engineers object to specifying the use of a particular paint or other similar coating, the product of a single maker, believing that this prevents competition in bids and results in the payment of a higher price than would otherwise be necessary. They also seem apprehensive that such a course may injure their reputation by the suggestion that they receive a commission from the manufacturer. As to this latter point, the writer does not believe there are many engineers whose characters are not good enough to clear them from any such suspicion, and those who cannot be indifferent to such a matter probably have not a great deal of reputation to be damaged. An engineer or architect should regard his employers' or clients' interests as though they were his own, and if he thinks the best results are likely to be obtained by using a particular paint or varnish, he ought to call for it in his specifications; and the man who acts on that principle can safely leave his reputation to take care of itself.

It is perfectly easy to get a competitive price. Let the engineer, before writing his specification, ask the price from the manufacturer; he can thus protect the contractor, for while the manufacturer cannot guarantee the durability of his material, which depends in great part on the preparation of the surface and the care taken in applying the coating, he can always tell the price. That is the only thing he can properly guarantee. There are too many engineers, and some of them holding high positions, who seem to think they are not doing their duty to their employers unless everybody they do business with loses money. No more ruinous idea than this can be held. No business man wants to do business with any one who is not making a profit and who consequently has an incentive to give satisfaction.

Business Principles.—Too many professional men are uneducated in business and are ignorant of the principles by which it is conducted, the most fundamental of which is that in any legitimate business transaction both parties are benefited. Any man who systematically attempts to buy supplies for less than they are worth is thereby thrown into the hands of sharpers and cheats, who try to satisfy him while giving him inferior material. Perhaps it is not right to call them cheats, for our courts have decided that a man who contracted for and paid for a turpentine japan at less than the price of turpentine was not defrauded when he received a benzine japan and could not recover payment, for it is assumed that he could not legally expect to buy a thing for less than it cost. This was a famous and well-known case; and the guilty man is the one who, in the first instance, tries to perpetrate the fraud. The employers of such men deserve whatever they get.

The engineer must make up his mind in some way that it seems wise to use, on a particular structure, some special paint; then he ought to specify that clearly, with the name and address of the maker if possible, and let the contractor know at once exactly what will be required. This tends to remove from the latter a temptation to supply an inferior article and makes it far easier to have proper inspection. If, in addition, the manufacturer is notified and told who will buy the materials and the quantity required, the chances are ten to one that he will make a special test to see that they are not for any reason below the standard. The maker takes far more interest in such an order than he does in goods for miscellaneous trade, to be used he knows not by whom, or how, or where. Fair and straightforward treatment will always secure the interest and cordial co-operation of the manufacturer. It is not straightforward to say that the paint used shall be either of those made by Jones, by Brown, or by Robinson, when everybody knows that Jones sells his paint at $1 a gallon, Brown at $1.25, and Robinson at $1.50. This is merely an attempt on the part of an engineer to "save his face," as the Chinese say; it deceives no one; it is undignified; it gains the respect of none and forfeits that of many. On public works the law sometimes requires such subterfuges, and then they may be excusable; but the actual result of such restrictions is that in the purchase of that class of supplies for which accurate descriptive specifications cannot be written, some execrable materials which would not be considered for a moment by any intelligent private citizen have to be accepted. There is no part of our public service which stands in greater need of reform than this matter of purchasing supplies.

CHAPTER XVIII.

WATER-PIPE COATING.

THE engineers of water-supply are constantly in trouble on account of the corrosion of the metal pipes used in conveying water. Nearly all of these pipes are iron and almost all the large pipes are of cast iron. This metal does not rust as readily as wrought iron or steel, and it is necessary to make it much thicker than steel because of its inferior strength and greater brittleness and also because it is liable to have thin or defective spots, which is not the case with steel or iron pipe. It does not therefore rust through, as a rule, as easily as the others. On the other hand, it is not as tight, it is liable to leak at the joints, and to be broken by the unequal settling of the earth about it, and on account of its greater weight it costs more, at least in large sizes, say above 4 feet in diameter.

Rusting of Cast Iron.—Rust is, however, a very serious cause of trouble with cast-iron pipe; it causes the surface to become rough, and this interferes with the free flow of water. Cast iron is not a homogeneous material, and rusting begins at spots where the chemical action is most strongly induced, which may be due to galvanic action due to the proximity of portions of different composition, or often to the leakage to the pipe of an electric current from an outside source. The spot becomes covered with a mass of hydrated sesquioxide of iron, very bulky in proportion to its weight (and its weight is two-thirds greater than that of the iron which it contains), and this coating is believed to act catalytically to induce further corrosion; at any rate, the spot soon becomes covered with a nodule of rust, projecting an inch or two, and sometimes much more, into the interior space; this not only

Sections of Enamelled Pipe, 5 by 25 feet, weight 5 tons each.

diminishes the cross-section of the opening, but, what is still more important, sets up irregular and vortex currents which very seriously affect the free flow of water through the pipe.

Diminished Flow.—The rough surface thus produced also serves for a foothold for algæ and other vegetable growths, which attach themselves to the wall of the pipe and float in the current of water, from which they derive their sustenance, and to which in some instances they impart taste and odor, the combined result being that often the flow of water through a long water-main is diminished 25 per cent., and sometimes 50 per cent. or more. It is, therefore, desirable for more reasons than one to prevent corrosion, even in cast-iron pipes; as for steel pipes, these are so thin that comparatively little corrosion causes a leak, sometimes amounting to a serious failure of the pipe, and must be prevented at any cost.

The R. Angus Smith Patent.—What may be regarded as the beginning of the modern practice of pipe-coating was the invention of Robert Angus Smith, Ph.D., F.C.S., a citizen of Manchester, England, and for a long time Secretary of the Literary and Philosophical Society of Manchester. He was the author of many scientific papers, and at the request of the society prepared a Memoir of John Dalton, the eminent chemist, who was also a member of that soceity. Dr. Smith (who was not a medical man, but a scientific chemist and a physicist) was applied to for advice in the matter of protecting the water-pipes laid down by the city of Manchester between 1845 and 1850, probably because he was the secretary and permanent executive officer of the society before mentioned, which included many eminent technical and scientific men of Manchester and neighboring cities. The result of his investigations and experiments is set forth in the patent for coating pipes which was issued to him October 19, 1848, and is No. 12,291 of the British Patent Office. In the specifications he says that "the coal-tar" (which was the principal ingredient, in his estimation, of his coating) "is first to be reduced by distillation or otherwise, so as to obtain the product, which consists of a thick pitch-like mass; this is to be kept at a temperature of

300° F. (or such a temperature as will keep the matter fluid). The pipes to be coated are first to have their interior surfaces cleansed from oxide, so as to offer a clean metal surface, which I prefer to coat over with linseed-oil. They are then to be heated to 300° F. in a suitable stove, then immersed in the melted coal-tar and remain there an hour." He also recommends the addition of linseed-oil to the coal-tar to keep it of the proper consistency; and although it is known that he also made various compounds of coal-tar containing Burgundy pitch and other resinous and oily substances, in this respect exactly agreeing with the practice of the varnish-makers of the time, it is clear that his primary and essential compound was composed of coal-tar distilled until it became a sort of artificial asphalt, which would not easily be further changed by the action of air or water because it had lost all its easily volatile constituents; this coal-tar pitch, the residue of distillation at 300° F. or over, was brittle, and to make it tough and elastic it was softened with linseed-oil; and this compound of linseed-oil and coal-tar pitch was used either alone or compounded with other oleo-resinous ingredients. The coal-tar pitch was cheap, and its cheapness made it practicable to get such a compound applied to low-priced material; and this, I presume, was the occasion for his saying in his claim, "What I claim is the coating of the interior of water-pipes by coal-tar by the aid of heat." As a result (probably an unforeseen result) of this wording of the claim it is legitimate for all users of a coal-tar coating to call it the "Angus Smith Process," although we cannot doubt that he would have unhesitatingly condemned the current modern practice, both as to materials and mode of application.

> "The evil that men do lives after them;
> The good is oft interred with their bones."

Let us note particularly some of the details of his process. In the first place, he distilled the coal-tar until he got a pitch-like residuum, which required a temperature of 300° F. or over to keep it fluid. This is the hard pitch prepared for roofing-pitch before the latter has been tempered with softening ingredients; it is hard enough to be brittle when cold.

Pitch and Linseed-oil.—This hard pitch can be compounded with linseed-oil, which will not unite with liquid coal-tar; on this point see the experiments of T. H. Wiggin in the Journal of the Association of Engineering Societies (Boston), vol. 22.

A Clean Metal Surface.—This compound of hard pitch and linseed-oil was applied, not to an uncleaned pipe, but to a pipe prepared by having "the interior surface cleaned" (not merely from dirt and sand, but) "from oxide so as to offer a clean metal surface"; there is no ambiguity about that. Dr. Smith was a man distinguished for his literary and scientific attainments, and knew exactly what his words meant.

Linseed-oil Coat.—The inside of that pipe was pickled with acid, and the "clean metal surface" was then coated with linseed-oil, put in "a suitable stove," and baked at 300° F. Then it was ready for the pitch and linseed-oil compound, in which it was immersed for "an hour" at 300° F.; then it was taken out and the residual heat in the mass of the metal pipe baked it on in a thin film. Note especially that the first coat of linseed-oil was baked on, and that in this perfectly oxidized and hardened condition it could not dissolve in the secondary coating, even when immersed in it an hour. In another part of the patent specification he advises that the hot pipe, when it has been removed from the oil- and pitch-bath and partially drained, should be slushed with linseed-oil, to help remove the excess of compound, and says that part of this last application of oil will run back into the tank and help to keep it properly tempered.

There is no doubt that pipe treated in this way will stand service; we can improve on the details, with our greater knowledge and resources of materials, but we have not done it with cast-iron pipe, nor has any such pipe been as well coated since his time.

Present Method.—The current practice is thus described by Mr. Wiggin, and as the pipe was made for the Metropolitan Water Supply of Boston and vicinity, it was probably as good as could be had in the country:

"The inspector having passed judgment on the pipes, they are rolled along down to the coating apparatus. The apparatus consists of a number of ovens, with iron cars, on which the pipes are rolled into the ovens and on which they stand during heating, a vat or tank for the coating compound, a crane for hoisting the pipes in and out of the vat, and various brushes, scrapers, and mops for brushing out dirt and removing surplus coating material. The coating material is crude gas-tar with sometimes some dead oil of tar added. The pipes are given a fairly good brushing before being put in the oven. The oven is merely an enlarged chimney-flue, for all the smoke and gases of combustion pass in at one end and out at another, so that a light but visible deposit of soot is made on the pipes, which is not brushed off. The old-fashioned ovens have simply a square hole through the floor of the oven, connecting it with the fire, so that the hot gases, and occasionally flame, act principally upon one portion of the pipe, heating that portion very hot before materially affecting the other portions. The newer ovens are fitted with an arched bottom, with bricks left out at intervals all along the pipe, this arrangement causing a more uniform temperature. The pipe is left in the oven until the attendants think (no thermometer is used) it is heated to about the correct temperature (48-in. pipes are left in about twenty minutes); then it is put in the tar to stay from a moment to ten minutes, according to the condition of the work about the vat. On being removed from the vat, the pipe is allowed to drain over the vat, and the drainage is aided by scraping the invert with a segmental hoe, made to fit, or at least to be of smaller radius than the pipe. The pipe is then lifted out onto the skids and the coating smoothed up further—surplus tar removed and thin places reinforced—by a brush or mop. The brush is better because the mop leaves part of itself behind on the pipe. The coating becomes hard in from half an hour to two hours, according to conditions.

Kind of Tar Used.—"Coal-tar varies very widely according to the coal used and the temperature maintained in the manufacture of the gas. Furthermore, coal-tar varies at the different heights in the tank in which it is collected at the gas-works. But no tests are made to obtain any particular kind of tar for coatings. The unrefined overflow from the hydraulic main of the gas-plants is purchased where it can be obtained easiest and cheapest. Specifications often call for deodorized tar, but the most noticeable thing about coating-tar is its dense and pungent fumes when heated.

"In summer tar is usually more fluid than molasses; in winter it has often to be melted out of the barrels. This crude tar cannot be used as a paint for cold surfaces, because it will not harden; and tar from the coating-vat, though always somewhat refined by the continued heating, does not harden sufficiently when applied to cold surfaces. This suggests the philosophy of the whole tar process of coating. By the heat of the pipes the tar is distilled down to a compound which is solid at atmospheric temperatures. A very favorable condition for this volatilization of the liquefying constituents (which are also the most volatile constituents) evidently exists when the tar is exposed to the air, spread, as it is then, in a thin film over the hot pipes; and that rapid volatilization takes place at this time is indicated by the dense fumes given off.

Importance of Temperature.—"As a corollary to the foregoing, it follows that the temperature of the pipe, as it emerges from the bath, is one vital factor in the character of the coating. If the pipe is too hot, the coating is overdistilled and becomes too brittle, or even may be reduced to an earthy, carbonaceous residuum. If the pipe is too cool, a thicker coating is formed, which will not harden sufficiently, will come off on the skids, and will run in warm weather.

"At one foundry the pipes are often wittingly underheated on days when strong north winds prevail, because the wind makes it difficult to heat the ovens, and the day's work must be done just the same. Again, pipes which stay in the oven during the dinner half-hour are liable to go into the tank too hot, because they are left in the oven too long and are not allowed to cool down. The writer has often seen very hot pipes lowered into the tank, when they caused a violent boiling and much yellow smoke (yellow smoke is the founder's sign of an excessively hot pipe). An inspector said that at one foundry pipes hot enough to set fire to the tar are so common that lids are rigged so that they can be rapidly unhooked and allowed to fall over the tanks and smother the flames.

"In general, the men fall into a certain routine of work,—so many pipes to brush out, so many to mop out, so many to roll into the oven, etc., between dippings,—and this routine fixes the time of heating. A good dipman will not allow any noticeable errors in temperature to pass, but he will not delay the routine for minor errors. In other words, the application of the method is inferior to the best judgment of the dipman.

"The character of the tar in the bath is another important variable. New tar gives softer coatings, other things being equal, because it contains more of the lighter constituents. Thick tar gives thicker coatings than thin tar. Fresh tar requires a hotter pipe than does old tar. Regularity in adding new tar would give greater uniformity in coatings, but tar is often not in stock when it is needed, and the dipman does not care much, so long as the coating passes, and the inspectors do not usually pretend to know much about coatings or to judge them very harshly.

Dead Oil.—"Specifications often call for the use of dead oil of coal-tar in the dip. The misconception is probably often entertained that dead oil bears to tar-coating a relation similar to that of linseed-oil in paint. A better comparison would be that between dead oil in coal-tar and turpentine in paint. Dead oil is of use principally to thin back the tar when it becomes thicker than the dipman likes it. Ordinarily the necessary adding of fresh tar is sufficient to keep the tar thin."

Such is the character of the coating for cast-iron pipes at the present time. All the progress which has been made in the last half century has been in the direction of cheapening the material without regard to its quality, and of simplifying the process so as to turn out a maximum amount of product with a minimum of plant and labor. The result more than justifies

Mr. Wiggin's remark that "perhaps, if the truth were known, the modern crude-tar coating would be found to be living on the hard-earned reputation of the linseed-oil coating"; and this is called the Angus Smith coating, though there can be no doubt that if he were living he would condemn the whole thing from beginning to end; in fact, though the use of his name may, on account of the peculiar wording of his patent claim, be legally justified by a technicality, it is unfair treatment of the name of an able and careful man, amounting to breaking the seventh and eighth commandments, by adulterating his invention and stealing his reputation.

Coatings on cast-iron pipes serve sometimes another purpose. Small sizes of pipe are thin, and if the iron is not of the most suitable quality they are liable to be porous. An old foundryman who practised for many years the manufacture of small pipe, a man in whom I have the utmost confidence, says that when he was making pipe it was all tested by hydraulic pressure, and new pipe was very frequently leaky, by reason of minute sand-holes. This was in Wisconsin, and gas-tar was unknown at that time in that part of the country; so the pipe was put in a bath of strong salt water for twelve hours and then exposed to the air for a few days, when it was found to be perfectly tight, the openings having been closed with rust. Obviously a coal-tar dip would accomplish the same result. This is in line with the current practice of shop-painting corrugated sheet iron, which is often so full of pin-holes as to be unsalable unless it is painted. The paint usually applied to corrugated iron is more expensive than coal-tar, costing about twenty or twenty-five cents per gallon.

Tar Not Used on Steel Pipe.—It has always been recognized that a coal-tar coating is not good enough to be of use on steel riveted pipes, or on steel or iron welded pipes. Very large pipes are usually made of steel plates rolled to the desired form and riveted, the operation of making them being practically like making the shell of a steam-boiler. These pipes are commonly made up in three sheet sections, 25 to 30 feet long; these are coated and then are shipped to the point where they are to be laid. The steel sheets are received at the shop in most cases perfectly clean and free from dust, their surfaces being covered with blue mill-scale very thin and adherent. When these are passed through the bending-rolls they are of course put under a strain, for sheets a quarter to a half inch in thickness do not bend very easily, and this breaks loose all the scale which is at all disposed to come off, so that even without pickling or sand-blasting the surface is really in very good condition, not of course as good as if entirely freed from scale, but much better than that of any other structural work in its natural state.

Dipping in Asphaltum.—These sections are then heated and dipped into a vat of coating material, which is also hot; usually this is a horizontal vat, and the pipe is rolled into it and rolled over in it by means of chains which go around the pipe and which form a sling for handling it; the pipe is then lifted from the vat, not quite in a horizontal position, but with its axis inclined ten or twenty degrees, and the surplus coating runs out of the interior and off from the outside back into the tank. It is held thus over the hot tank, the heat from which promotes the draining, until it ceases to drip; then it is removed and allowed to cool. The coating compound is a soft asphaltum, made softer than its natural state by the addition of mineral-oil residues of high boiling-point; as this oily matter gradually evaporates out it is replaced by further additions from time to time. Much of this pipe-coating material is known as maltha, and is separated from California petroleum as a residue left in the retort after distilling off the more volatile portions of the natural oil. The longer this process of distillation is carried on the thicker and harder will be the residue; so the maker prepares two kinds, one of which is perhaps a little too hard for use by itself and the other much softer, and by mixing these the dipman can get a compound of any desired degree of hardness.

Various Kinds of Asphaltum.—Asphaltum is the name of a class of minerals related to petroleum-oil, from which geologists think it is derived. Petroleum, according to Dana, passes by insensible graduations into maltha, and the latter as insensibly into solid bitumen; some of the solid asphalts, such as Trinidad, while hard enough to be brittle when struck are soft enough to be viscous and flow under long-continued pressure; the more fluid of these cannot be made to unite freely with linseed-oil. From these we gradually pass to gilsonite, a much harder substance, which shows no viscosity at natural temperatures, but is yet perfectly fusible and is called by mineralogists a resinous mineral or a mineral resin. It is nearly free from mineral oily matter and hence unites readily with vegetable oils; and we may pass beyond this to the mineral known as albertite, which is almost or quite infusible and differs from bituminous coal chiefly in structure and in the nature of the products of decomposition obtained when it is subjected to intense heat. This latter does not soften with oil and is of no interest in this connection. The semi-fluid and tarlike bitumens are known by the name of maltha, an old Greek name applied to these substances by Pliny, and still used with that meaning; and, as has been said, it is also applied to the bitumens artificially prepared from petroleum, especially the dense and bitumen-bearing sort found in California. Maltha greatly resembles in appearance coal-tar or coal-tar pitch, but is very different in its chemical properties, and the one cannot be substituted for the other.

Defects in This Coating.—When pipe sections have been coated in the way described, it will be easily understood that the compound runs off more from that side of the pipe which chances to be uppermost while the pipe is being held in its approximately horizontal position to drain, and will be thickest on the opposite side; alike on the interior and exterior of the pipe. Usually it runs off until there is a thickness on the thin portions of $\frac{1}{20}$ to $\frac{1}{50}$ of an inch; on the thicker portions, it may be $\frac{1}{16}$ to $\frac{1}{4}$ of an inch; but it is not uncommon to find pipe sections with a thickness of 1 or 2 ins. of coating along the side which was the bottom when the pipe was draining. The compound is heated in the dipping-tank to about 300° or 350° F., and the mineral oil, which is the softening ingredient, constantly distils off, so that the composition continually changes, and no two successive pipe sections are coated alike. When the mixture gets so viscid that it will not run off the pipe with what the dipman regards as reasonable freedom, he adds a barrel or so of thinning compound, and the next few pipes get a coating as much too thin as that on the preceding ones was too thick. The specifications usually say that the compound shall be of such a nature that it shall not be brittle in cold weather nor run or be sticky in hot weather; as a matter of fact, it is brittle under a blow always, and in hot weather masses of it weighing several pounds will slide off the outside; and on the inside, where the pipe lies so that the thickest part of the coating is at the top, it runs down in stalactitic forms, sometimes extending across the whole diameter of the pipe; and I know of places where workmen had to be sent through the pipe to break out these obstructions. Asphalt compounds of this sort are, at ordinary temperatures, fairly hard to the touch, and if struck with a hammer are more or less brittle, yet they yield to gentle continued pressure. If they can be got into service without injury they last a long time, because they are perfectly impervious to water, and are only destroyed gradually from the surface, not all at once throughout their whole thickness as a porous substance would be; and as they are buried in the earth and filled with water they change temperature but little and that little with almost inconceivable slowness, so that they do not crack with changes of temperature. The thicker such a coating is the longer it is likely to last after once it gets into service; but the thicker it is the more difficult it is to handle during the three to six months, or sometimes more, which elapse between the time of coating and the testing of the line, after which it can be covered with earth. Before that time it is subject to misuse of more sorts than the inexperienced reader can imagine.

Handling of Pipe.—Usually it is loaded on open railway-cars, on which it is piled up, one section on the top of another, and the rivet-heads dig holes in the coating; but sometimes this is in part prevented by laying old rope or other packing material between the pipes. The posts on the sides of the car scrape off some during transit; and when it arrives at the point of destination by rail the pipe is rolled off the car without very much ceremony; sometimes it rests on skids, sometimes on the ground. After it has been there a few days or weeks, during which time boys pelt it with stones and hammer it with cudgels to hear the pleasing and resonant sound it emits, and play hide-and-seek in it, it is loaded on farm wagons and hauled over country roads and across fields, sometimes as far as fifteen miles, and dumped by the side of the ditch on the gravel and loose stones which have been excavated; then it is partly slid and partly lowered into the ditch. There one might suppose it

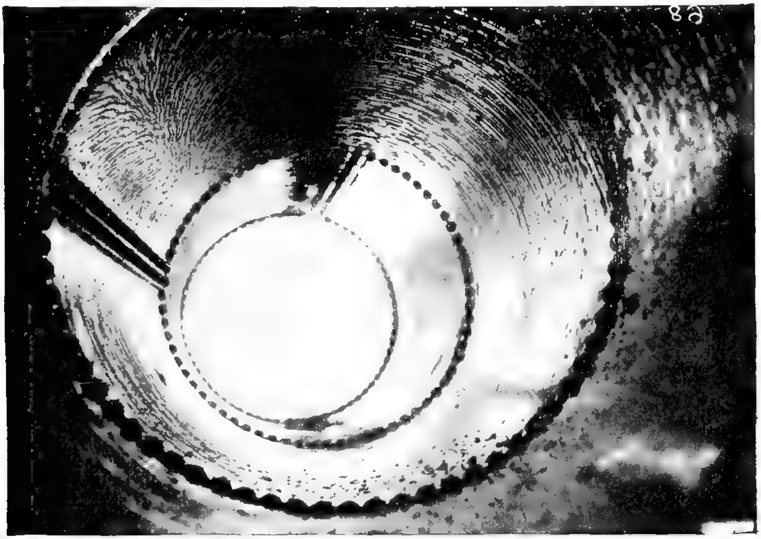
> "...sleeps well.
> Malice domestic, foreign levy, nothing
> Can touch him further."

Not yet. The sides of the ditch are covered with fresh earth, poor walking in dry weather and banks of mud when it rains; but the pipe lying in the ditch makes a beautiful asphalt walk, and is used as such not only by the curious rustic and the casual visitor but also by the entire gang of laborers going to and returning from work. Thus a large part of the coating on the outside of the top is removed; and if it is at all brittle, on cool mornings the vibration from people walking over it cracks it off from the inside of the upper segment. This kind of thing may be called the "malice domestic." Then comes the "foreign levy" in the shape of a gang of tramp riveters to do the field riveting. They are armed with sledges, hammers, crowbars, and chisels; part of them work inside the pipe and part on the outside. They wear hob-nailed shoes; their sensibilities are not attuned to the highest pitch of refinement. The pipe had a good coating to start with if there is much left on it when they get through. And over all arches the clear blue sky, from which the July sun shines down, and its heat is reflected from the yellow sides of the ditch, and is absorbed by the black pipe until it is so hot that one cannot hold the hand on it, and if the coating is at all viscous it softens and slides off from the outside, and on the inside forms great tears and stalactitic shapes. Then it rains, and all the bare places, inside and out, get rusty. And the chief engineer objurgates and deplores, and when he wants sympathy has to look for it in the dictionary.

Repairs.—These defective places in the coating are repaired by painting. Long before the experiments on paints and varnishes described in the previous chapter were made, the waterworks engineers had found out that no reliance could be placed on oil and pigment paints for hydraulic work; and the coating most commonly applied is a sort of spirit varnish, made of the same asphalt compound used in dipping the pipes, dissolved in some volatile solvent, either turpentine, benzine, or bisulphide of carbon. All these form inflammable vapors which are explosive when mixed with air, hence incandescent electric lights, the wires of which are most carefully insulated, are the only source of light which should be used; and as these vapors are unhealthful, and that of carbon disulphide in particular is extremely poisonous, the pipe should be ventilated by blowing a steady blast of air through it from the direction from which the painters enter the pipe, so as to blow against their backs and always carry the gases from them. This is a precaution which should never for a moment be omitted; men have lost their lives or become insane from inhaling some of these gases.

If the varnish thus applied does not make a very thick coat, two or three coats should be used; the more the better, for the pipe will never again be so accessible. It is possible at this time to use an elastic oleo-resinous varnish, one containing asphaltum, and this is, in my judgment, the best thing to use, but it is slow to dry unless a current of air is passing through the pipe, which is often the case. Not less than two coats of such a varnish should be used. On the outside of the pipe it is often possible to apply some of the hot, melted compound, such as was used in the dipping-vat; it may be melted by the side of the ditch in a kettle and applied with a swab or brush, or sometimes poured on from a ladle.

Corrugations.—Pipes coated in this manner frequently, perhaps I may say commonly, exhibit ridges and furrows occasioned by the irregularities of flow of the compound while draining; the accompanying illustrations show the character of these, both on the outside and inside of the pipe. On the outside they do little harm; on the inside they seriously diminish the flow of water by causing eddies and irregular currents.



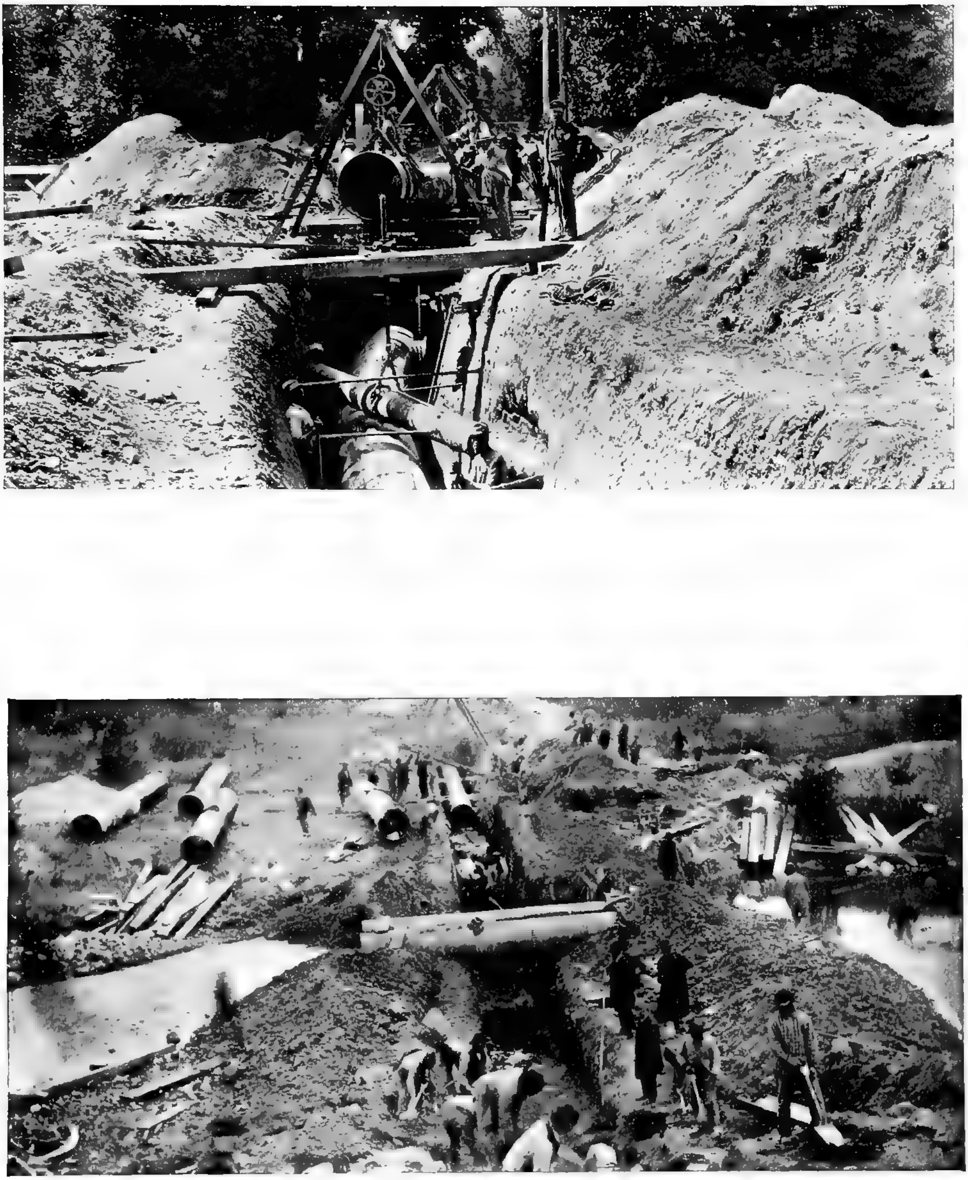
Vertical Dipping-tank.—An attempt has been made to improve on this method of dipping by using a vertical tank in which the pipe section is entirely immersed; it is then slowly lifted, endways of course, and as the lower end of the pipe is in the liquid, the cold air cannot get in, and so the compound does not chill, but runs off smoothly, from the inside; and this improvement makes it possible to use a compound which has a much higher melting-point than that used in the horizontal dipping-tank, which will in consequence be unaffected by the heat of the sun. Such compounds have been made; I do not know their composition, but I imagine from a rather hard asphalt, perhaps from "gilsonite seconds," inferior gilsonite from that part of the deposit of mineral which has been exposed to the weather, softened with a very thick and heavy mineral lubricating oil from which all the products except those of very high boiling-point have been distilled. These compounds have a considerable degree of toughness even when quite cold, and stand transportation and rough handling very much better than the ordinary coating, such as has been described. The temperature of the dip is about 400° F., and the compound sets and ceases to run on the outside of the pipe while still far too hot to be touched by the hand; it does not flow off well from the exterior surface, and men stand around the mouth of the tank when the pipe is being hoisted out with scrapers and scrape off as much as they can from the surface back into the tank. The compound sets so rapidly that it is often possible to see the marks of these scrapers on the finished pipe. I think they are liable to scrape it off too closely, leaving too thin a coating on the outside. I have myself seen sections of such coated pipe which had been exposed to the weather for a few weeks which had considerable areas of coating so thin that in a favorable light I could see the metal through the coating; and where the weather had removed the elastic ingredient from the superficial layer I could with my finger rub off all the coating and expose the clean metal; the coating, being extremely thin, had become earthy and friable, and could be easily rubbed off by friction. Of course such a coating was no protection; but the inside of these same pipes was well and uniformly coated and most of the outside had a fair coat. A coating of this sort, if properly applied, ought to give good service. Its principal defect, which it shares with the asphalt dip previously described, is that the elastic ingredient is a mineral oil which becomes lost by diffusion, and leaves the asphalt, or rather the asphaltene part of the asphalt, in an earthy and friable condition; this action takes place from the surface and consequently does not rapidly produce a decomposition of the coating as a whole, but it is progressive and is the principal cause of the failure of asphalt coatings, which after a long time become earthy and lose their coherence throughout and cease to afford protection; and long before they reach this stage the deterioration of the surface makes it a suitable foothold for algæ and other aquatic growths. I suppose that a compound could be made of asphaltum tempered with linseed-oil which would be much better, but it would be costly and has never been attempted.

Varnish Enamels.—The oldest varnish-makers and users of whom we have any definite record, artisans of the tenth to the fifteenth centuries, knew that varnish applied to metal and then hardened by baking made a coating of great durability. This probably was discovered by observing that the more elastic varnishes are the more durable, and then that these varnishes, which contain a large proportion of oil, are slow to dry, and not very hard when they are dry. No doubt varnishes were in those days much slower than are those of approximately the same composition to-day, because they did not understand the refining of oil as well as we do, nor was their knowledge of varnish-making in its details to be compared with ours. But human nature has been about the same, and when a knight got a new sword-hilt he probably did not bring it in to be enamelled until the day before the tournament, and had to have it back that same afternoon. Thus the enameller, although he was ignorant of the fact that the activity of the ions was augmented by an increase in temperature, learned to observe that varnish dried more quickly if exposed to heat, and he put the varnished hilt in the oven and baked it for two or three hours, and everything was satisfactory.

The materials were not very costly and the process was simple, so that all sorts of small metal objects were treated in this way, not only for ornament, but for common use; and the practical details were well understood long before any one cared about the theory of the matter.

The Rochester Pipe-line.—Only small things were treated in this way. When freshly varnished objects are put into an oven the volatile solvent, turpentine or benzine, is quickly evaporated, and this causes danger of fire; and this has the effect of prohibiting such work on a large scale; but when, in 1893, I was applied to by the authorities of the city of Rochester, N. Y., for advice as to the best way of preserving their new water-main from corrosion, I decided that this must be the process, and that it must be so modified as to make it practicable. The pipe in question was an intake from Hemlock Lake, and was for most of its length a 38-in. steel riveted pipe; the coating was the common asphalt or maltha dip, and was not satisfactory, for the reasons which have been indicated in the foregoing account of that process. It seemed to me that the best coating which could be applied would be a true varnish enamel. While it was true that fairly satisfactory results had been obtained on cast-iron pipe by Dr. L. Angus Smith with a sort of an enamel of coal-tar pitch and linseed-oil, this could not be depended on for steel pipe, for the following reasons:

The R. Angus Smith Process Not Suited to Steel Pipe.—In the first place, the Smith coating was baked on by the residual heat in the pipe after coming out of the dip; this could be done because the weight of metal was very great, but steel pipe is thin and does not hold much heat. Second, it was not a rational method. As has been seen, the pipe was first dipped in pure oil, then baked, then again dipped in an oil and pitch compound, then rinsed off with oil, and the final baking was partly a process of oxidizing the oil and partly hardening the pitch by evaporating its volatile constituents, which, however, could have been present in only small amounts. The final result would, of course, depend on the proportion of oil in the coating, which must have



Laying Water mains of 40- and 38-inch Steel Enamelled Pipe.

been quite variable, and the thickness, and consequent rate of cooling, of the pipe. The pipe was not coated with a definite compound; and the oil and pitch were not united by cooking together, as is the practice of the varnish-maker. Third, it was expensive; the pipe practically had two coatings, one of oil and one of the indeterminate mixture, and the results would depend on the skill of the operator in a rather excessive degree. Fourth, cast-iron pipe does not need such perfect protection as steel pipe, as it is not so much inclined to rust and is much thicker, and a coating which might answer for one would not do for the other, as in fact was agreed by everybody, and the modern coal-tar coating was not to be considered. But asphaltum is a substance which can be had of a definite composition and character, in any quantity desired, and it is greatly superior in every way to coal-tar pitch; and if the pipe were baked in an oven it could be exposed for any desirable period to any desired temperature; hence we can not only temper the coating compound with just enough oil to make it slightly tough, but can put in all the oil we need to give it any desired degree of elasticity, because we will leave the coated pipe in the oven until the coating is perfectly and exactly oxidized. Besides all this, the coating thus applied is thin and hence much less costly than it would be if as thick as a common asphalt dip, so that in making such an enamel we are not restricted by cost to asphaltum for a resinous ingredient, but can use in addition any other resins of low price, and some of the low-priced varnish resins are of a high degree of excellence in everything except color, and the oil can be properly refined, and the compound made up according to the best knowledge of the varnish-maker.

The Sabin Process.—The danger of fire was avoided by the simple means of leaving the turpentine or benzine out entirely; the compound was of course thick and stiff at ordinary temperatures, but by heating it in a tank to about 300° F. it became fluid, and was applied by dipping the object to be coated in it, precisely as though it were an asphalt or a coal-tar dip. After dipping the pipe was at once put in a suitable oven and baked until the coating was properly oxidized. Of course, such a compound and such a process were far more expensive than the coal-tar dip as used on cast-iron pipes; but that had nothing to do with the question. It was not excessively costly as compared with a good asphalt dip, nor in fact very much more so; and it was not a matter of stopping up sand-holes, nor of making the pipe look as though it had been coated, but of securing a really adherent and preservative film which would endure tolerably well the unavoidable rough handling which sections of water-pipe receive. About 14 miles of 38-in. steel pipe was coated in this manner for this Rochester conduit, and the work was done with remarkable uniformity. Considering the fact that this was the first attempt to coat large work of any sort in this way and that the apparatus and process of handling were in a large degree experimental, the uniform and excellent results obtained not only reflect credit on the operators but show that the process must be in its nature reasonably simple and easy to conduct. The pipe sections were 28 feet long and weighed about 2 tons each, part of them 2¼ tons; they were after coating transported on wagons to the place of use, the distance being in some cases 14 miles, over very ordinary roads; and it was the general opinion of all who saw the work that the coating stood the necessary handling extremely well. Of course, the rivets of the field-riveted joints had nothing on them, and their heat destroyed the coating with which they came in immediate contact; but these places were painted with an air-drying varnish of composition similar to that of the baked coating, as were also all spots from which the coating had been abraded, which were, however, very few and small; for not only does such a coating stand hard usage well, but on account of its beauty and apparent delicacy it actually gets much more careful treatment from the workmen than does a coarser and rougher one.

Character of the Coating.—A coating of this kind is hard and elastic enough to stand a smart blow with a hammer without injury, but anything can, by the application of sufficient force, be scraped off any metallic surface. It is, however, a mistake to compare a pipe-line to a chain, whose strength is that of its weakest link, and say that its protection is measured by that of the least protected spot; if this were so, there would be no water-pipes in use.

Corrosion is Local.—As a matter of fact corrosion is not uniform and general, but local; and if 99 per cent. of the surface is protected the durability of the pipe is probably increased at least 90 per cent. I have seen old pipe with practically no coating removed from a bed of blue clay without the least rust on it; but we must remember that the coloring-matter of clay is iron, and in blue clay it is in the ferrous condition, not saturated with oxygen; when we burn blue clay it becomes red because the iron in it becomes more highly oxidized. Hence it is plain that blue clay may act as a reducing agent, not as an oxidizing one, and tends to abstract oxygen from anything with which it is in contact; and it is well known that peat does the same thing. So it is that in one place a pipe may tend to rust and in another it will be preserved, independently of the effect of a coating; and the fact that we cannot attain absolute perfection in a pipe coating is no reason why we should not apply as good a protection as is available.

The Allegheny and Cambridge Lines.—Owing to the importance of the subject, the novelty of the method employed, and in no small part the high reputation of the engineer in charge (Mr. Emil Kuichling), this Rochester pipe-line attracted a great deal of attention; and a similar coating was applied, the year after this was finished, to the pipe-line at Allegheny, Pa., which was nearly 10 miles in length and 5 feet in diameter,—at the time, I believe, the largest pipe-line in the world,—and to a conduit in Cambridge, Mass., about 4½ miles long and 40 inches in diameter. The pipe sections at Cambridge were of about the same dimensions as those at Rochester; for the Allegheny pipe they were only 25 feet long, but as they were 60 inches in diameter, and the steel plate of which they were made was ½ inch in thickness, they weighed 5 tons each. The oven constructed for handling these enormous pipes had a capacity of eight sections, and was divided into four parts, so that one part of the oven could be opened without cooling off the other three. Two hours was required for baking and about an hour was used in charging and emptying the oven, so that eight pipe sections could be baked every three hours, or the oven could be charged and emptied eight times in twenty-four hours; or sixty-four sections a day, equal to 320 tons; and this was actually accomplished. When finished, the pipes were tested by pounding them at intervals of a foot or two with a ¾-in. steel rod, and if any of the coating could thus be loosened it was rejected; but it was necessary to recoat only a few of these sections, perhaps a dozen out of the nearly 2000 which were made. Since then this process has been applied to ordinary small sizes of steam-pipe, for electric conduits, and other uses, and I have seen ½-in. pipe which had been coated bent around a post into a coil with an internal diameter of about 8 inches, without cracking the coating, which was so hard that it could not be scratched with the thumb-nail; and in one establishment as high as 28,000 linear feet of pipe has been coated per day.

Used in the U. S. Navy.—Not long after the completion of the work which has been described the Bureau of Construction and Repair of the U. S. Navy Department built a coating plant for using this compound, which by this time had become known by the name of the Sabin compound (and the method as the Sabin process), in the New York Navy Yard at Brooklyn. The especial use to which the naval authorities put it is for the protection of fire-mains and flushing-mains on board ships. The former of these in particular have been a source of a great deal of trouble. Although made of heavy copper of the best quality they rapidly corrode, not uniformly, but holes appear, the corrosion taking place from the inside, which is filled with sea-water under a pressure of 100 to 150 lbs. to the square inch. These pipes sometimes last only two months, rarely twelve, and formerly had an average life of about six months. Since using this coating they have lasted three and four years, and their ultimate durability is not yet determined. This coating is, consequently, specified on all war-ships; and at most of the navy yards and at several private yards plants for its application have been constructed.

It may here be said that in 1903–4 the steel underfloors of the roadways and sidewalks of the Williamsburg Bridge over the East River in New York City were pickled and coated by this process in a manner quite satisfactory to the engineers in charge, and that this was the second lot of structural steel (except for ship-building) to be pickled in this country; undoubtedly the first to be pickled, dipped, and baked in any country.

The proper application of such a coating requires a film of uniform thickness to be spread over the surface of the metal, and that this should be oxidized to a certain normal point corresponding to the complete and perfect oxidation of linseed-oil to linoxyn, or "oil-rubber"; but the oxidation should not be carried beyond this point, or the coating will lose its elasticity, and, if carried much beyond it, its adhesiveness to the metal. In order to get this uniform film, the object to be coated is thoroughly cleaned, heated a few minutes in a hot oven, and dipped in the hot compound. It is well known that all metallic surfaces have normally an adherent film of air, which is removed only with difficulty, and the easiest way to break up this adhesion is to heat the metal. The hot liquid, therefore, wets the hot metal much more readily and perfectly than a cold liquid will wet a cold metal; and as the heat is maintained for a considerable time the liquid gradually crawls over any minute uncovered portions and in this way a perfect and continuous contact between the metal and the coating is established. This is promoted by the strong capillary attraction which exists between the compound and the surface of the metal, especially if the latter is iron or steel; much less attraction seems to be manifested between the compound and zinc, brass, or even copper, although the latter two are constantly being coated at the Navy Yard plants.

Details of the Process.—The object to be coated is left in the dipping-tank two or three minutes, then taken out, held over it to drain for a short time until the greater part has run off, but not until the compound appears to be thickening with cold, then put in the hot oven. Ordinarily about twice as much compound will adhere to the object as is needful to form the coating. The surplus runs off and is caught in a convenient receptacle, from which it is returned to the dipping-tank. If it were left in the oven it would be wasted, and would, moreover, be carbonized and fill the oven with smoke, to the injury of the coating. Commonly it takes from fifteen minutes to half an hour for the surplus coating to run off; and it is necessary that the oven should be hot to promote the rapid and perfect drainage, for if any part of the coating is too thick it will not be oxidized as soon as the rest and will make a soft and imperfect spot in the coating. This is a matter of the utmost importance; and it is, therefore, essential that the oven should be uniformly heated and particularly that there should be no leaks or crevices through which the cold air from without can get in, for a jet of this cold air would infallibly make a bad spot on the coating. The tendency of the hot air to get out and of the cold air to enter is very strong, because at the temperature of the oven, 400° F., the density of the outer air is twice that of the hot air in the oven. After the coated object has been in the oven about two hours it is done, and when removed and cooled it is ready to be put in service. It is not to be forgotten that the object of heating the oven is to increase the chemical activity of the oxygen and of the oxidizable material, and that the same results may be reached by baking at a lower temperature for a longer time, or at a higher temperature for a short time. The principal difficulty is in the matter of drainage; if the oven is not fairly hot the drip does not run off properly, and if it is very hot it may not be uniform. Some things can be coated and the excess wiped off; wire, for example, after dipping can be drawn through a hole in scraper which will allow only the exact amount needed to go on into the oven, and I have in this way baked a good coating on wire in twelve or fifteen minutes at a temperature of 500° to 600° F. This is rather delicate work, because it is necessary to know exactly the temperature, and from previous experiments exactly the time required, and remove the wire at just the right time, or it will be overbaked and brittle. It could be easily done on a large scale automatically.

The Dipping-tank.—The dipping-tank may be a horizontal trough or a vertical tank of cylindrical, oval, or other convenient horizontal section; for coating straight pipes nothing is better than a vertical cylindrical tank, about a foot larger in diameter than the pipe. If the pipe is not straight the tank may be made oval, or the lower part cylindrical and the upper part oval. Such a tank will naturally be made of riveted steel and must be heated by an external flue. It is impracticable to heat such a tank by a steam-jacket or to heat any tank with a steam-coil; for by the continual heating and cooling, rivets will get loose and leaky, and the joints of a steam-coil, though when new they may be tight at 1000 lbs. pressure, will in time leak a little; and a very slight leakage of steam into the compound will in time destroy it. The tank should never be exposed directly to the fire, but it may be conveniently heated by a flue which intervenes between the furnace and the chimney. The whole should be well insulated to prevent radiation, and it is to be remembered that neither in the dipping-tank nor the oven is there any evaporation of liquid, hence very little fuel will be needed if proper insulation is secured.

Treatment of the Compound.—The heating-flue should never come up as high as the lowest level which will ever be reached by the compound in the tank; if it does, the part of the shell of the tank above the level of the liquid will be overheated, and as it is alternately wet and dry as the level is disturbed in use, it will be covered with thickened and overcooked compound, which will from time to time be redissolved in the liquid, which is thereby made thick and viscid, far more than would be supposed; for it is a peculiarity of varnishes in general that an overcooked portion of varnish continually grows thicker until it becomes a jelly, and what is more remarkable, it imparts this property to fresh and uninjured varnish to which it is added. In this way it acts exactly as though it were a ferment. I do not suppose it is a ferment, though some enzymotic ferments act under about as unlikely conditions; but the chemical character of these changes is unknown.

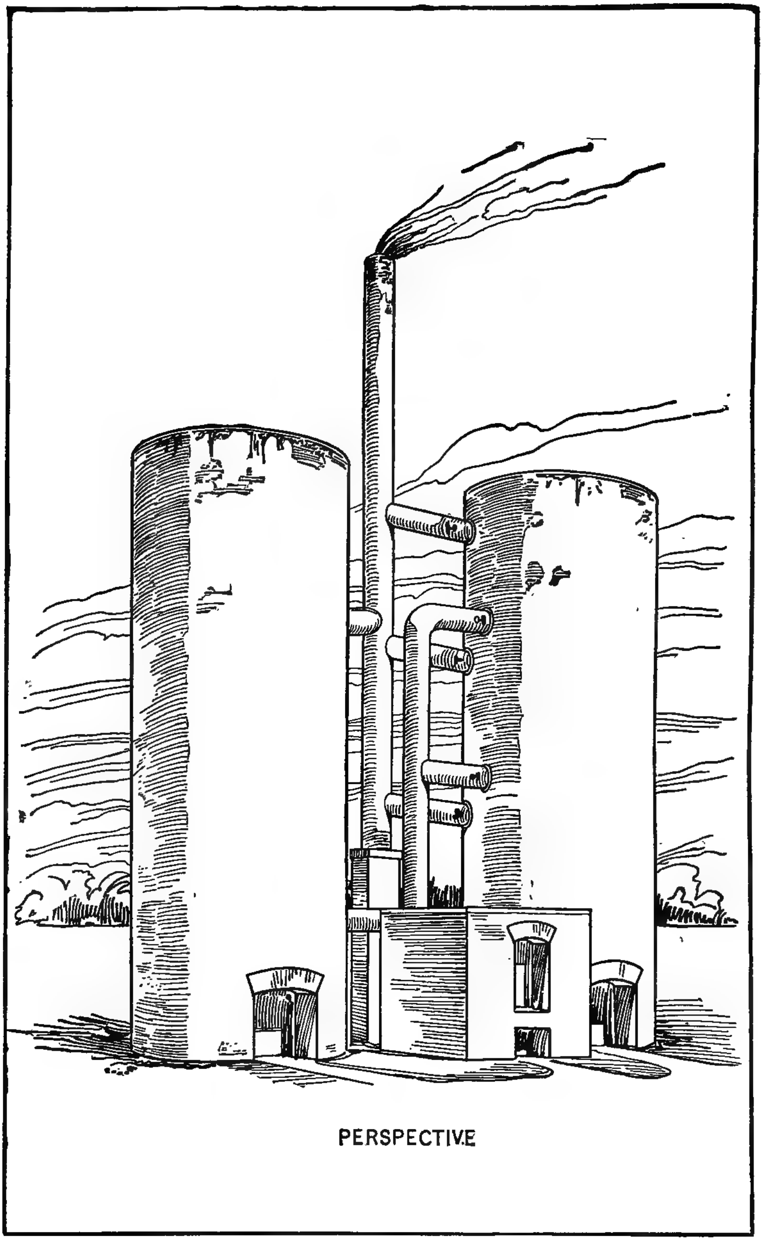
So far as I know, overcooked oil does not act in this way, but only the compounds containing oil united with resinous matter. An overcooked varnish may be thinned with spirits of turpentine, and will keep growing thick, until an incredible amount of turpentine has been added without avail; but turpentine is not necessary, for this pipe compound does the same thing and there is no turpentine in it. It is a strange thing, but it is true nevertheless, and if the compound in a tank gets overcooked, all that can be done is to throw it away and clean the tank out absolutely clean, so that not a trace of the old compound is left in it, before refilling it. If the compound is only a little thickened it may be thinned with a properly made thinner, which is a similar compound made with a large excess of oil; but this is a makeshift. The man in charge of the work should be strongly impressed with the great importance of not spoiling his compound by overheating it, which he is most likely to do by trying to heat it from a cold condition too quickly. It should be heated very gently; if there is a large amount, the heating should be begun the day before it is to be used. Of course, when the work is continuous from day to day the heat is never allowed to go down altogether. But no amount of care will avail if the heating-flue extends above the level of the liquid in the tank.

Horizontal Tanks.—Instead of using a vertical tank, horizontal ones are in use in some of the navy-yard plants. These are more convenient for dipping objects of irregular section, or with projecting parts, as such things, after being heated in the oven, may be laid in the tank and the hot compound poured with ladles over the uncovered parts. It is, besides, possible to get along with a less amount of compound in those tanks; and if made in the way I shall describe, one end of the tank may be heated (for coating small articles, such as pipe-fittings) and the rest of the tank left cold. It is not a good plan to make such a tank of steel plate and heat with a flue, unless it is for larger work than has yet been done. It has recently been proposed to coat bridge members in this way and very likely a horizontal steel tank might then be the best; but for ordinary work a horizontal tank should be made in cast-iron sections, each section being a short, wide, and deep trough with open ends; the ends should be flanged, and the sections should then be bolted together to make a long trough, the ultimate ends of which may be closed with plates bolted on. Each of these sections should be cast with a steam-jacketed double bottom, like a soap-kettle; and these should be separately piped, each with its own independent inlet and outlet, for steam at 60 or 80 lbs. pressure. These steam-jackets, being made of cast iron without rivets, cannot leak into the compound, and it is impossible to overheat the latter. Several of the sectional tanks have been built and are giving the greatest satisfaction. If only one section is desired, a steel-plate diaphragm may be put in to divide the compound in this section from the rest of the trough; as there is no hydrostatic pressure there is no particular tendency for the compound to leak by, and that in the rest of the tank remains unmelted. The disadvantage of this kind of a tank is that it exposes a large surface to the air and the compound tends to oxidize in the tank; it is not as rapidly worked nor as convenient as a vertical tank, especially for pipe; only one piece can be dipped at a time, and in coating small pipe it is common to dip a hundred at a time in a vertical tank; and it is more difficult to keep dirt out of it. Everything which goes into an oven has to drip, consequently most things have to be supported with their longer axis vertical. Pipes can be baked in no other position, and so nearly all ovens are vertical; if the tank is also vertical, the top of it may be level with the top of the oven, which is in many ways convenient. A pipe-coating plant should be built on a vertical plan throughout if at all possible.

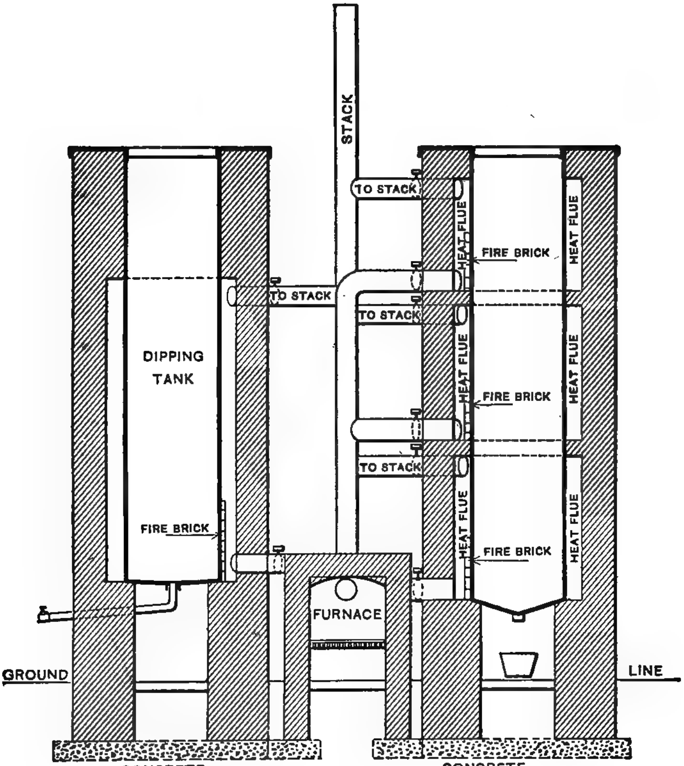
The Oven.—The essential thing about the oven is that it should contain pure hot air. The process is one of oxidation, and the carbonic-acid and other gases from the furnace should not be allowed to enter, nor should the smoke and ashes; it may be heated by an external or internal flue or flues, or the air which it contains may be heated in an external stove and forced into the oven with a blower. On very large work the latter would be the best, as it would insure steadiness and uniformity of heat. Further, the oven should be of such a shape that the coated object can be supported in it, either by suspension or by resting on a grating in such a position that it will drain quickly and uniformly; it must be so tight that drafts of cold air cannot enter; and the bottom of the oven must not be heated, because the drip will fall on it drop by drop, and if it is hot these drops will char and be destroyed and will fill the oven with smoke. This drip must be caught in a removable drip-pan, and by it run off into a convenient receptacle which can from time to time be emptied into the tank. There must be some means provided for varying the heat in the top and bottom of the oven, so that if one part is too hot the heat may be partly withdrawn and diverted to another. This may be effected by having two or three entirely separate heating-flues: one, for example, to heat the lower part of the oven, another for the middle region, and a third for the upper portion. Or it is possible that a single flue, surrounding the oven, with an outlet to the chimney near the bottom and several separately controlled inlets at different heights from the furnace, might be efficacious. It has also been proposed to cause the air to circulate vertically in the oven by withdrawing it from the bottom and blowing it in near the top with a blower. Of course, if the air is heated with an external flue and blown in it will be easy to arrange the heat as we choose. Provision of some sort should always be made in an oven of more than 12 ft. in height for local heating.

The common and very satisfactory kind of oven for pipe-work consists of a steel cylinder, not less than 1 ft. larger in diameter and 2 ft. greater in length than the largest pipe which is to be put in it, securely set up in a vertical position, and surrounded with a 16- or 20-in. brick casing, to keep the heat in. Between the steel shell and the brick wall is a space of 6 ins. to 1 ft. in width all around, as a flue for the products of combustion from a neighboring furnace on their way to the chimney. This flue envelops the steel shell from top to bottom (but does not extend under the bottom of the oven) and may be divided by one or two horizontal annular partitions into two or three independent flues. The top of the oven is covered with a light cover, usually made of sheet iron backed with a layer or two of asbestos-paper, and then with inch-boards; the cover keeps the heat in, and can be easily lifted off by a couple of men when it is time to remove or put in pipe. A gallery for these men to walk on is provided, a couple of feet lower than the top of the oven, and this may extend to and around the top of the dipping-tank, if the latter is of the vertical type. If more than one section of pipe is to be coated at once, as many of these ovens as are desired may be built together in the same mass of brickwork; each steel shell may be made large enough to take in not more than two large pipe-sections at a time. If the units are made larger than this trouble will be experienced on account of the escape of great quantities of hot air whenever the oven is opened to take out or put in a pipe.

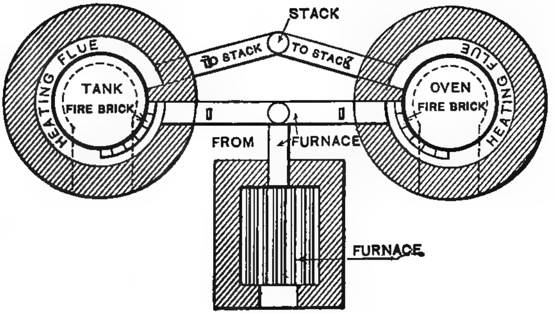
The dipping-tank and oven must be inclosed in a well-lighted, substantial building which can be heated in winter to a temperature of not less than 60°; for if the pipe is taken out of the dipping-tank into cold air or into a wind of even warm summer air the compound on it will be chilled and will stop running off; three or four times as much as is proper will be carried over into the oven, and before it gets off some of it will have begun to set from the heat and chemical action, and then it never will run off, and the pipe will be unevenly coated. It is therefore important to have the whole apparatus inclosed in a building. And if the pipe is to be lowered down into the oven from the top, it is clear that the building must be somewhat more than twice as high as the oven, and some kind of hoisting apparatus must be provided; an electric crane is probably the best if much work is to be done, but a derrick with a swinging-boom has been used, also a trolley, and for occasional use still simpler apparatus has been made to answer. The height of the building may be sometimes lessened by sinking the ovens and dipping-tank below the level of the floor. If this is done a blower, made especially for hot air, such as is used instead of a chimney to induce draft, may be used to force the hot flue gases from the furnace to the



Enamelling-plant, Sabin Process.



VERTICAL SECTION



PLAN

Enamelling-plant, Sabin Process.

oven; in some situations it is possible to build on a side hill and excavate on one side. This is an almost ideal state of things. Ovens opening from the side, with a door like a closet, have been built. They have so far been not very successful. The trouble is that there is leakage around the door, no matter how carefully it is made, and that side of the oven is cooler than the others. An oven is now in process of construction on this plan, but is built with a sort of vestibule, so that leakage into or out of the oven is into a little room intermediate between the outer air and the oven; this ought to be more successful.

Enamelling-ovens have been built which consisted simply of brick rooms heated by iron pipes which passed through the room and radiated heat which was supplied by the furnace gases passing through these pipes; this is a very simple and efficient form; if carefully made, it should be susceptible of the most exact adjustment of temperature. This style of oven has been used for such things as bicycle frames and the like, never for very large work.

In any oven it is important to have thermometers. Nothing is equal to a good mercurial thermometer within the limits of its range, and they can now be had with nitrogen over the mercury, instead of a mercurial vacuum, which can be depended on to 800° F.

Thermometric Readings.—Any mercurial thermometer has range enough, if constructed for the purpose with a long stem, for this varnish enamel work. Two or three tubes of common steam-pipe should penetrate through the brick wall, the flue, the iron shell, and enter an inch or two into the oven; thermometers attached to a rod can be pushed in as far as these pipes go, and the outer ends of the pipes plugged with a handful of fibrous asbestos; from time to time a thermometer may be drawn out and read. A thermometer may also be lowered from the top with a wire. It must be remembered that the temperature indicated by the thermometer may not be the actual temperature of the greater part of the oven; the thermometer may be in an under- or over-heated place, but since it is always the same place,

Laying Water-mains of 40- and 60-inch Steel Enamelled Pipe.

it is sufficient. The operator finds that when the thermometer gives certain readings the baking is successful, and then he always tries to keep the temperature at these standards. The apparent temperatures of different ovens, doing practically the same work, are usually different; the real average temperature must be about the same. When the plant is properly constructed almost the whole thing is a matter of temperature.

(The foregoing chapter on water-pipe coatings was written in 1903; and after some hesitation the author has decided to leave it as it was originally written.

The use of a baked enamel coating for water-pipe appears to have been abandoned. The U. S. Navy Department used it for about ten years, but finally gave it up, substituting a heavy lead lining for salt-water pipes, the first cost of which is enormously more, but is warranted by final economy. Uncoated pipes used to last about six months; enamelled pipes lasted two and a half years (average), but lead-lined pipes are expected to be permanent. The objection to its use on large water-mains is primarily the difficulty and expense of applying it. Large experience has shown that metal which is to be thus coated should be first cleaned by pickling or sand blasting; and the cost of doing this added to the cost of a suitable plant for dipping and baking, is regarded as a serious obstacle to its use.

It is also a quite legitimate objection that the coating thus made is very thin, and although small objects so coated may be handled carelessly, very heavy ones are likely to have some of the coating scraped off. Moreover, considerable improvements have been made in the materials used for the ordinary dip. The writer is nevertheless convinced that when properly used no other coating is equal, in general, to a well-made enamel. He has seen a straight 10-ft. length of enamelled ½-in. pipe bent into a coil of three folds, and then left in a 10-per cent. sulphuric for a week without injury; as much as thirteen million linear feet of pipe has been thus coated in a year. Enamelling had never been done on a very large scale until the work here described was undertaken;

now it is very common; and it may be that some time in the future it may be revived for similar work. The manufacturing profits have not been enough to push it. The historic and intrinsic interest of the matter seems sufficient to warrant leaving the chapter as it was originally written.)

CHAPTER XIX.

SHIPS'-BOTTOM PAINTS.

THERE are several species of aquatic animals which bore holes in unprotected submerged wood, and are particularly dangerous to the bottoms of wooden ships. To protect ships from these the practice arose of covering the exterior of the ship below the water-line with sheets of copper, as a sort of armor-plate against aquatic enemies. It was found that not only did the copper protect from the teredo, but that barnacles and other organisms did not adhere to it, and this was a great advantage, because frequently these growths were several inches in thickness, and impeded the rapid progress of the ship through the water. A coppered bottom is, in fact, very efficacious at first; it does not appear that it is actively poisonous to barnacles and the like, but that it has a laminated structure, probably from having been rolled, and under the action of sea-water the exterior laminæ scale off, and of course any marine growth attached falls off with the scale of copper.

Exfoliation Said to be Superficial.—It is said that this lamination is most marked near the outside of the copper sheet, and that the middle part (in thickness) of the sheet is of more homogeneous, unstratified metal; so that after a few years the laminated part wears off, and then the copper ceases to exfoliate, and the barnacles and other things grow as well on the copper as they would on anything else.

When iron ships came into use the danger from the teredo disappeared, but the loss of speed consequent on fouling with barnacles, weeds, etc., was as serious as ever; and as the speed of steamships increases the objection to fouling is greater. Chief

Constructor Bowles is authority for the statement "that while the fouling of the battleship Indiana between her launching and trial was very slight, it was sufficient to make a difference to the builders of $100,000 in the premium earned for speed. It probably increased the resistance of the ship about 15 per cent. A ship subject to ordinary service, staying in port about half the time, will foul so rapidly that in from six to nine months there will be a loss of speed of from 25 to 40 per cent.; where ships are running rapidly and regularly the loss is less." (Trans. Am. Soc. C. E., Vol. XXXVI, p. 494.) The prevention of fouling of iron and steel ships is therefore a matter of great and practical importance; and as this is attempted almost entirely by painting, it is proper to give the subject consideration here.

I say almost entirely; for if we attach plates of copper to the outside of a steel ship, as soon as the sea-water gets in between the two, as it is sure to do, galvanic action sets up and the steel is rapidly corroded.

Wood Sheathing.—It has been thought that if there were no metallic connection between the steel and copper this action could not take place; so in many cases the outside of the ship has been sheathed with 3 or 4 ins. of wood, in the form of planks bolted on, and the copper sheathing attached to the wood. This has not been successful because the wood becomes water-soaked, and thus a galvanic couple is formed. It has always seemed to me that this method might be made far more successful by kiln-drying the wood, then soaking it for a day or two in melted paraffin, until the latter had penetrated the planks to the centre. During this treatment they would shrink 10 per cent.; then if they were applied and closely fitted on, and all interstices filled with melted paraffin or some similar material, the water never could get in to do any damage. Of course it would cost money, but the relative cost would not be so very much more, and if it were efficient, and the other way is not, it would be the way to do it. There would still be the objection that copper sheets cease to exfoliate after two or three years and would have to be torn off and replaced; but the planking would not need renewal. If a ship can be kept really clean by recoppering every two years, or perhaps three, without any other trouble, it might be worth considering.

Electroplating the ship with copper has been unsuccessfully tried. Electroplate, if of considerable thickness, is a spongy deposit, and does not answer.

Paint, then, is practically the universal means of protecting ships' bottoms. All sorts of nostrums have been tried for the purpose. The vagaries of inventors are infinite and unaccountable, but none are quite so absurd as some of the patented preparations which have been—not designed (they couldn't have been designed)—put together to sell to the seafaring man. Here is a sample:

A Sample Patent.—"I take 100 lbs. of rosin-oil, 100 lbs. of black lead, 50 lbs. of French chalk, 50 lbs. of white zinc, 75 lbs. of oxide of iron, and 25 lbs. of tallow. These ingredients are thoroughly mixed. I then heat together 125 lbs. of thick turpentine, 50 lbs. of linseed-oil, 125 lbs. of common rosin, 25 lbs. of Gallipoli oil, and 125 lbs. of tallow; and when the mixture is cold I mix with it 25 lbs. of shellac dissolved in 50 lbs. of alcohol or naphtha. I then add to the mixture 50 lbs. of Venetian red, 125 lbs. of zinc paint, and thoroughly mix the ingredients. I then add to the mixture 50 lbs. of tar-spirit and again thoroughly stir the mixture. The two compositions thus formed are then thoroughly mixed and the paint is ready for the market."

This mixture was patented by an Englishman, both in England and America; and while it is more elaborate than most it can hardly be said to be more absurd or less efficacious.

Practically there are now in general use three kinds of ships'-bottom paints. All require a first coat, which is essentially the same in all cases, being a quick-drying spirit varnish. This is said to prevent rusting, and is called the anti-corrosive coating as distinguished from the second or anti-fouling coating.

Copper-oxide Paint.—In the first class of these anti-fouling paints the pigment is oxide of copper, which is claimed to be poisonous. This is mixed with a varnish similar to that used with the anti-corrosive paint, which latter has commonly an oxide of iron as its pigment. I am told that 6,000,000 lbs. of copper scale (oxide) are annually used for this purpose in the United States. The efficacy of this class of paints is a matter of dispute. I believe that neither the navy or any of the more important steamship lines use these paints, whose most undeniable merit is the moderate price at which they may be sold. Their very great sale, on the other hand, may be taken as clear proof that they are not worthless. I have had no personal experience with them, my own experiments having been along a different line, as will be told later.

The Varnish Used.—The varnish used in these paints contains little or no oil, but is made of a cheap grade of Kauri or some similar resin dissolved in benzole or some solvent of which benzole is a considerable ingredient, some cheap grade of coal-tar naphtha, mixed probably with a little benzine, and sometimes with a little wood-alcohol and fusel-oil. As they are used in the open air the odor of these liquids is not particularly objectionable; and it would make no difference if it were, for an oleo-resinous varnish is not good for such service, and it is necessary to use a solvent which will dissolve a suitable resin. Paints of this sort dry in an hour or two, so that the second coat may be applied almost immediately.

It is not impossible that the resin itself is repellent to the organic growths, at least in some degree. I know of at least one very successful maker of this kind of paint who believes that the copper oxide he uses is chiefly valuable as a selling feature and that the varnish, which is of a peculiar kind, is what keeps the barnacles off. There may be something in this. I am certain that the common buffalo-moth can be kept out of rugs by varnishing the floor on which the rug is laid, two or three times a year with a good Kauri varnish; and some other insects, equally objectionable, will not come into a house, the entire woodwork of which is kept well varnished. We know that these oleo-resinous varnishes continue to harden for a year or more, which shows that some slow chemical action is going on, and although we can detect no odor it must be that something objectionable to the more acute sensations of insects is being given off. I have no doubt about this, although I do not understand what takes place. But if this is so, it may be possible that the right kind of a varnish may prevent the adhesion of marine growths to the bottom of a vessel. It is all a question of evidence, and I am not aware that a sufficient amount of evidence is accessible.

Poisonous Ingredients.—The same kind of a varnish is used with the second sort of paint, but the pigment is usually iron oxide or something of the kind, to which has been added from half a pound to a pound per gallon of some mercury compound. Some makers claim to use oxide of mercury, others chloride; probably it makes little difference, as it is converted into the extremely poisonous bichloride of mercury (corrosive sublimate) by the action of sea-water. This, of course, kills anything which tries to adhere to its surface; and as the varnish is gradually worn off fresh supplies of poison are exposed, until the anti-fouling coat is practically gone. Arsenic does not seem to be efficacious; mercury is practically the only poison in use. Paints of this sort, if well made, are very satisfactory; but they are expensive, and of course have to be renewed frequently. The rule in the navy is to repaint the bottoms of ships every six months. The time varies according to the kind of service, the temperature of the water, and many other things; the same paint will seldom give similar results twice on the same boat.

Copper-soap Paint.—The third kind of paint is of an entirely different nature. It is essentially a copper soap, made by precipitating a common soda soap from solution by adding a solution of sulphate of copper, making a stearate or oleate of copper; with this is probably mixed some tallow or other grease. The mixture is made liquid by heat and is applied in a melted condition with brushes, exactly as melted wax was used on ships' bottoms two thousand years ago, as described by Pliny. This paint is applied in a rather thick layer, about $\frac{1}{100}$ in. in thickness, and is slowly worn off by the action of the water as the boat moves rapidly through it. Its action is therefore similar to the exfoliation of copper, and is quite effectual. It is claimed by those who sell it that the bottom of the boat is by its use rendered slimy, and thus the friction is decreased; but it is to be noticed that racing yachts use a hard varnish, which may fairly be taken as a demonstration that the soap paint has no superiority in that respect, though it certainly does seem to be very smooth.

In 1900 I prepared carefully thirty plates painted with various anti-fouling coatings, which it had been determined by previous experiments to investigate. These consisted of (1) an oleo-resinous varnish, containing rather more than 30 gals. of oil to each 100 lbs. of Kauri resin; (2) a spirit varnish made by dissolving Manila resin in a suitable solvent; (3) a similar varnish, made from a more easily dissolved resin than Manila, but otherwise much like it; (4) shellac, in alcohol; and (5) a rather complex varnish containing a proportion of shellac, and also oil. The second, third, and fourth of these were also used with the addition of various fixed oils: linseed, tong, and castor. All were made into paints by adding a neutral pigment, unacted on by the varnish or sea-water; and each was tried with the addition of a mercury compound and also (separately) with arsenic. Some of the latter trials were duplicated, using in one case powdered metallic arsenic and in the other white arsenious acid. Some of the mercury tests were in triplicate, using 1 lb., ½ lb., and ¼ lb. of mercury to the gallon of paint. Besides these were half a dozen special paints, one of which (for purposes of comparison), was a well-known proprietary ships'-bottom paint of excellent quality. The result may be briefly told. The oleo-resinous varnish made a very fair paint, but was soft and would have been easily scraped off; the Manila varnish was hard, and with the addition of a little oil was a good paint; the other, more soluble copal, was not as good as Manila; the shellac went to pieces; so did the special paints; but No. 5, which was a mixed varnish, gave the best results of all, a little better than the standard proprietary paint, indicating that a little shellac and a very little wax are useful additions to such a paint. Kauri was the best resin; mercury was much better than arsenic; and a considerable proportion of mercury is desirable. The best paints were, unfortunately, the most expensive, and none of them showed much durability after a year's exposure; some were nearly destroyed before that time. No experiments in this series were made with the copper soap or grease paints, nor with copper oxide. It seemed possible to make a somewhat better mercury paint than is now in use, but not a great deal better; and the difficulty of carrying on these experiments is prodigious.

In conclusion it may be added that some of the yachtsmen, to whom expense is not an objection, varnish the bottoms of their vessels, sometimes with spar varnish and sometimes with a spirit varnish, and while the surface is tacky rub it over (with a brush) with copper-bronze powder; and this is said to be very excellent. Often the bronze powder is mixed with the varnish before the latter is applied. Racing yachts usually receive nothing but varnish, or a thin varnish paint, applied a day or two before the race. Probably no other surface offers so little friction as that of a clear, well-dried varnish.

CHAPTER XX.

SHIP- AND BOAT-PAINTING.

WITH a few exceptions the methods and materials used in house-painting are applicable to ships and boats, the most remarkable difference being in painting the outside of pleasure-craft, which are commonly white. This color gives a cool and agreeable effect; but as these vessels spend much of their time in harbor, and as harbor-waters are frequently covered with a black, slimy, oily film, they quickly become foul, and are then anything but pleasing to the eye. The remedy for this state of things is one which, from a painter's viewpoint, may fairly be called heroic.

White Paint for Boats.—To keep them white, they are painted with white lead, mixed not with oil but with spirit of turpentine. Paste white lead, containing 10 per cent. of oil, is mixed up with turpentine, and after standing overnight to settle, the turpentine is poured off; this removes about half of the oil. The residue is then mixed with fresh turpentine, and the boat painted with it. In this way is obtained a coating of unparalleled whiteness, for the yellowish tint of ordinary white paint is due to the oil it contains; but paint made in this way is necessarily lacking in binding material. It therefore washes off easily, and thus exposes a fresh surface. As it dries with great rapidity, owing to the small amount of oil it contains, and the excessive thinness of film which this oil has, it is possible to apply many coats in rapid succession, thus building up a thick coat of paint; and as there is nothing about it which has a natural affinity for water it does not become water-soaked and all come off at once from the surface to which it was applied, but gradually wastes away from the outside, or if necessary, may be cleaned off with scrubbing-brushes, thus always presenting a white surface of great purity. This, of course, means frequent repainting and a use of material which would in other cases be considered wasteful; but in no other way can the results be obtained.

On deck the conditions are very different. The deck-houses are sometimes painted, and this should be done with enamel paints, made with the most durable and elastic varnishes, say 25 to 30 gals. of oil to 100 lbs. of (unmelted) resin; the interior of the cabins and other rooms with a somewhat harder and quicker-drying enamel.

Spar Varnish.—Some of the exterior woodwork, frequently a large part of it, is left unpainted and is protected by "spar" varnish; this varnished but unpainted wood is called, on shipboard, "bright work." The masts are sometimes, but not commonly, painted, and the spars are left "bright." Spar varnish is used on these, and this is the origin of the name. Spar varnish is a very durable and elastic varnish, pale in color though not excessively so, for a yellow varnish looks well on spruce, and dark varnishes are much better than pale ones on mahogany and such woods, and should contain not less than 25 gals. of oil to 100 lbs. of resin. It is in fact very much such a varnish as is used for a finishing coat on carriages, except that it must dry more quickly. If a boat could be built in a shop and varnished in a room free from dust, carriage-finishing varnish would be better than spar; but in practice the quicker-drying varnish is the better. It is frequently a more fluid, or thinner, varnish than such as are made for shop work. This tends to make a thinner film, which is less durable, but is quicker to dry; and as most spar varnish is used on repair work, it is absolutely necessary that it should dry quickly. It is even the practice in some of the best yards to thin it with spirit of turpentine for very hurried work; and this is better than adding drier, though, of course, it makes a still thinner and more perishable coating than the regular spar. Sometimes spar varnish is applied to the unfilled wood, and repeated coats used until a sufficient body has been built up, and this is the best practice; in this way the wood is protected by a homogeneous coating which no severity of exposure can cause to separate; but often a cheaper varnish is used for the under-coat work. This should be similar in its nature to spar; rubbing-varnish is not fit for this, and worst of all is shellac. The latter is often used because of its excessive rapidity of drying; but as has been already stated, this rapidity is partly only apparent; and at any rate shellac is not a varnish which ought to be exposed to the hot sun, nor to sea-water, and not infrequently causes blisters under the spar varnish which is subsequently applied.

Shellac.—There is a legitimate use for shellac on board ship. Some of the decks, not exposed to the weather, but those which serve as floors, must be scrubbed clean daily; and as it is manifestly impossible to use a slow-drying varnish on these, the best thing is a thin shellac, one coat of which will dry almost immediately, and will answer, for a day or two, to prevent grease and dirt from penetrating the wood. This is especially the case on men-of-war, where large numbers of men are crowded into confined spaces, and the sanitary value of varnish is of the utmost account; not only does it keep out the dirt, but the strong alcohol and the resin both act as germicides. But nothing is more reprehensible than the practice which some captains have of ordering all the bright work varnished, over and over again, with shellac. It is not uncommon to see naval vessels come in from a cruise with the bright work so bedaubed and plastered with shellac that it was enough to discourage the constructor and the master painter from ever trying to make a ship look well. Spar varnish, and that of the best quality, and not too much of it, is the only thing which should ever be used on bright work; it may be cleaned and repolished as often as necessary. It is good practice to use spar also when it is necessary to thin enamel paints, rather than to use turpentine or oil; nothing is better for this purpose on land as well as at sea.

Ships are often repainted too much; a naval constructor told the writer that he had removed layers of paint which contained, when viewed with a microscope, over a hundred laminæ. It seems as though the officers who were responsible for this ought to be taught a little common sense. Yachts and other pleasure-boats are looked after with more intelligence in this respect, and are usually in admirable condition.

A white interior enamel is often made for some of the cabins of ships, especially in the navy, by mixing the pigment with damar varnish. This probably makes the whitest enamel; but it lacks durability, and especially very quickly loses its gloss. On vessels of any value it is advisable to use a better article, for a good oleo-resinous enamel, which is white enough for the finest house, is certainly white enough for a cabin; and it has durability. Damar dries more quickly, but never has as good a surface, and it is certainly better to use a more permanent coating.

CHAPTER XXI.

CARRIAGE-PAINTING.

To treat fully of the painting of carriages and coaches would require a volume, and volumes have been written about it; but the casual inquirer into the art may be satisfied with an outline of the methods and the principles involved. It has always been near the border between artistic and industrial painting, and its practitioners have held a high rank. Carriages must be pleasing to the eye; but still more they must be strong and durable, retaining not only their form and strength, but, if possible, their finish after exposure to the inclemencies of the sun, wind, mud, and rain.

Severe Exposure of Varnish on Carriages.—Pictures are protected by frames, hung on shaded walls, untouched save to remove carefully the dust which settles on them; furniture is indeed used, often carelessly, sometimes, though not usually, exposed to the sun, but at any rate it is protected from the snow and rain; but carriages are drawn by horses, or propelled by engines, rapidly through grinding sand, dust, mud, and exposed to injury from branches of trees and accidents of every sort, yet the surface must be polished and lustrous, and the moisture must be kept out of the wood, or it will fall in pieces. The deacon's one-hoss shay was, we may be sure, painted and varnished with a knowledge and skill which need not have shamed its historian; else there would have been no tale to tell.

It is a general belief that carriages are painted in a less durable manner than was formerly the practice; and this is in some instances probably true. It must be remembered, however, that where one carriage has lasted for a generation thousands have perished, leaving no sign, in a few years; and probably some of our posterity will point to a few long-surviving coaches of our own time as we do to the relics which have come down to us. It must be that there have always been, as there are now, good finishers and poor. The latter are soon forgotten if they belong to a former generation, but if they are our own contemporaries we not only remember them but unjustly judge their better fellow workmen from their work. This is indeed a general law. It applies not only to carriage-painters but to varnish-makers as well; and there will always be those who exalt the past at the expense of the present, and discredit the skilful workman because poor work is common. It has always been common, and it always will be.

Good Work is Slow.—It is said in the twenty-eighth chapter of the book of the prophet Isaiah that "he that believeth shall not haste"; and this may well be taken for a motto, not by carriage-painters alone, but by all who have to do with varnish, whether as makers or users, and perhaps by some other people. Good varnish is slow to dry, so is good paint; a job which must be hurried will lack in durability, but a job which takes a long time is costly.

It is in general true that it is essential to have a suitable foundation on which to apply a finish, whether for beauty or utility. Xenophon, who wrote, four hundred years before the Christian era, the oldest treatise on horsemanship with which we are acquainted, says that "just as a house would be good for nothing if it were very handsome above but lacked the proper foundations, so too a war-horse, even if all his other points were fine, would yet be good for nothing if he had bad feet, for he could not use a single one of his fine points." It is exactly so with painting; if the foundation be poor the subsequent work and material are thrown away. The basic material is wood; this must be properly treated to make a suitable foundation. In the first place it must be dry; not merely kiln-dried, but previously well-seasoned; but this is a matter which belongs to the art of the wood-worker. It must be so treated as to be damp-proof, and this involves filling the pores of the wood on both sides and on exposed edges;

not a place may be omitted. This is equally true of furniture, and in fact the finishing of the latter is based on the practice of carriage-painters.

Filling.—The pores of the wood, then, are to be filled; the first coat is usually linseed-oil, to which a little white lead has been added, just enough to color the oil. Some painters use varnish for the priming coat, but this is because they are in haste, and they use a quick-drying varnish, which is not as good as oil. In place of white lead some use finely ground silica, and some use yellow ochre, and many a mixture of these; but it is of little consequence in the priming coat, for this is chiefly oil, and the oil is really absorbed by the wood. The real surfacing now begins; and many men use many things. The object all aim at is to get a hard, smooth, level surface; on this the paint is applied, and then the varnish. If the foundation is too elastic it will not hold the surface in place, and the latter will crack, even though of tough and elastic material. These "elastic under-coat cracks" are sometimes very puzzling. The writer has seen them on the surface of a highly elastic varnish which had been applied, four coats in thickness, on a steel surface, as a protective material; the hot sun hardened the outside pellicle, and when it suddenly cooled—and all such exterior work is subject to frequent and considerable changes of heat—this surface cracked, because the under-coat was so elastic that it practically gave it no support. Such cracks are purely superficial, and are not likely to affect the protective action, but they ruin the beauty of the finished surface. Elastic under-coat cracks, then, must be prevented by making the foundation hard and firm, and gradually working up, by the progressive use of more and more elastic coatings, to the finishing varnish, which is as elastic as is compatible with a sufficient degree of lustre.

White Lead as a Filler.—At this stage the chief differences in treatment are in the use of white lead or of a filler composed of silex or silicates. The older practice is to use white lead, and this is susceptible of variations. The first method of using lead consists in painting the surface with a white-lead paint. This probably was originally white lead in pure linseed-oil, but at present it is made by thinning paste white lead (which is called by painters "keg lead") with half oil and half turpentine; the proportion of turpentine is increased often to five-eighths and sometimes to three-fourths; the greater the hurry the more turpentine is used; five-eighths turpentine is very common. This is well brushed out so as to make as smooth a coat as possible. It is followed by another coat of lead which is prepared by thinning paste or "keg" lead with spirit of turpentine; sometimes a little oil is added, not usually as much as 5 per cent. by measure. Paint made in this way will have a lustreless surface, called "flat" or "dead." Commonly a very little lampblack is added to the lead in both these coats, enough to produce a lead or slate color; and to hurry the work about 2 per cent. of japan is also used. The last coat should be applied with great care, to produce as smooth a surface as possible.

Rub-lead.—Instead of these two coats it is also a practice to use what painters call "rub-lead." This is white lead mixed with lampblack to a slate color and thinned with oil and japan. A considerable amount of the latter is used, often 20 or 25 per cent. This by good rights ought to be ground through a mill. It may be remarked that the lampblack is thought to add to the smoothness and flowing quality of the lead. This is made of such a consistency that it may be brushed on with a stiff bristle brush; and when it has been on long enough to set well and be decidedly stiff the lead is rubbed well into the pores of the wood; this is best done with the palm of the hand. In this way a very fine, dense surface is obtained, and after hardening two or three days it is ready to be sandpapered.

Knifing-lead.—More rapid work still is done by mixing lead to a putty and applying it with a putty-knife. For this purpose paste lead is mixed with about an equal weight or twice its weight of dry white lead (the larger the proportion of the latter the quicker it is to work, because the oil slows it), and with a mixture of equal parts of rubbing-varnish and japan; usually a little spirit of turpentine is added. In fact, painters of all sorts usually add a little turpentine to everything, without much thought of the consequences. It promotes the union of the different parts of a mixture, as it is a powerful solvent, and adds to the fluidity of the whole. This lead compound is, for very rapid work, colored to suit the paint which is to be used over it; otherwise it is tinted with lampblack. It is either put on with a putty-knife or is thinned with turpentine to a very heavy paint and applied with a brush, after which, as soon as it sets, it is worked into the wood with the flat blade of the knife, and always the surplus is carefully removed. Rub-lead is almost universally used on wheels and running-gear, and frequently on bodies; but knifing-lead is restricted to bodies, the process being adapted to flat surfaces.

These are the various ways in which lead is used as a filler. In all cases after it is thoroughly hard it is sandpapered to get a very smooth surface. If lead is not used a wood-filler is applied. This is of course a paste-filler, having a body of powdered quartz or some equivalent, often containing some white lead; and the liquid in which it is ground is a varnish. This is well rubbed into the wood with a stiff brush, and when dry and hard is sandpapered. Two or more coats are often applied.

Putty.—It is the practice of house-painters to putty holes and crevices immediately after priming; but carriage-painters usually wait until the filler is all in. The operation is the same, except that as the work is to receive one or more additional surfacing coats and is then to be painted, it is not essential to a fine finish that so much care be taken not to scratch the surface, and steel putty-knives are used. If there is a crack where there is a possibility of flexibility between two adjacent pieces of wood it is bad practice to putty it, as the putty will in time work loose and come out. Putty, on a carriage, is for nail-holes and the like. White-lead putty is universally used, usually mixed with some japan to make it harden very rapidly. Of course it is more durable if mixed only with oil, or perhaps finishing-varnish; but tough putty cannot be sandpapered.

We have now got the woodwork primed, filled (either with lead or prepared filler), and puttied. The next thing is sandpapering.

In fact the first thing is too, for before the priming is applied the painter should see that the surface is as level and true as possible, and if he cannot make the wood-worker turn it over to him in that condition he must do it himself, for that is the time when it ought to be done and can be most easily. Usually each coat from the priming up is sandpapered a little; but at this point, after the putty has been applied, the surface must be made as good as possible, and all dust be thoroughly removed.

Rough-stuff.—The next coat is rough-stuff. The makers of carriage-paints prepare better rough-stuff than the amateur ever makes; but in general it may be said that it is essentially composed of a silicious filler—not quartz, but some mineral silicate, ground to a moderate degree of fineness, mixed with some white lead; from a third to a quarter the weight of pigment may be lead, but as lead is twice as heavy as the silicate, the latter will amount to five-sixths or seven-eighths the bulk of the whole. Ochre is regarded by some as a valuable ingredient. The liquid is essentially a rubbing-varnish; the carriage-painter who mixes his own adds japan, but the paint manufacturer (who in this case is also a varnish-maker) makes a special varnish which possesses just the right qualities for the purpose without the addition of a needless amount of injurious driers. The thing aimed at is to make a sort of paint which will dry rapidly to a very hard surface, capable of being ground down to a smooth, glassy finish, and at the same time have about the same rate of expansion and contraction as the foundation on which it rests, so that it will not crack and come off. This is no simple thing to accomplish; and it is in general safer to buy of a maker who purchases his filler in lots of one to ten car-loads, and always uses the same materials, than to try to use those things which are bought in small quantities and from miscellaneous sources.

It is applied with the brush, and as it is quick to set it must be put on rapidly and smoothly with a soft brush and by a skilful hand. One coat a day can be put on; three to five are needed, and often the latter number is doubled. If the material is right it is not necessary to sandpaper or give similar treatment between coats in order to secure adhesion, but a substantial body may be rapidly built up.

Guide-coat.—It is usual to color the last coat with ochre or white lead. This is called a guide-coat, as it serves as a guide to uniform rubbing of the surface. After a sufficient amount has been laid on the whole should be allowed two or more days to harden. It ought to be as hard as it will become, and time is well spent waiting for it to dry.

Pumicing.—This is not sandpapered, but is brought to a surface with pumice and water; and in this case the pumice is not powdered, but blocks of natural pumice-stone, which is a sort of porous lava, are used. These are sawn to the desired shape, ground down on a flat surface, and they are ready for use. The lightest and most open pieces cut most rapidly; the more dense are used for finishing. The rubbing is not done with circular or irregular motions, but back and forth in the same direction. The surface is kept well wet with pure water, but not flooded; but it should be frequently washed off and examined. It is sponged off with a clean sponge, and wiped dry with a clean piece of chamois leather. This operation is to be learned by experience and observation, not from books. It is one which requires patience and skill, and produces the surface on which the color and varnish are to be exhibited.

Color.—The next step is the application of the color. Paint for carriages is made of the necessary pigments, ground to the last degree of fineness. They ought to be ground as fine as artists' tube-colors; but instead of being ground in oil they are ground in "grinding-japan," a sort of varnish, loaded nearly to the point of saturation with lead and manganese driers. Not all colors can be ground in the same medium, or they will gelatinize and spoil. Such must have a special varnish or japan, the nature of which must be learned by experiment. These "coach-colors" are sold in air-tight tin cans, well filled, and the best of them will not keep forever. They should be purchased from fresh stock as they are needed. Varnishes improve with age, but no paint does, and coach-colors are, though perhaps not as bad as var-

RUBBING VARNISHED SURFACES IN A PIANO FACTORY.

By the courtesy of the W. W. Kimball Co., Chicago.

nish-enamel paints, worse than those ground in oil. Coach-colors are sold in what is practically a paste form, and are to be thinned with oil and turpentine. Some use varnish instead of oil, but the latter is generally advised. They are put on in thin coats and dry rapidly.

Rubbing-varnish.—Over this is applied rubbing-varnish in full, heavy coats. These do not depend entirely on oxidation for hardness, for rubbing-varnishes contain only from 6 to 12 gals. of oil to 100 lbs. of resin, and the large proportion of the latter helps materially to give them hardness. They should, however, be allowed ample time to dry. They are called rubbing-varnishes because they are hard enough to bear grinding down to a smooth, even surface with pumice and water; but in this case the blocks of stone are not used. The pumice is powdered, and is applied with a piece of thick felt, well wet with clean water. Several coats of rubbing-varnish are applied; not less than three, often more. Each coat is rubbed; the first lightly, the others more thoroughly. Before rubbing the surface is wet with clean water; then the wet pad of felt is touched to the powdered pumice and the rubbing begins. This is an art and must be learned; but the observer will notice that the expert uses steady strokes, all in one direction; at first rubbing lightly, aft rward with more force. The edges and mouldings are first treated, and the workman finishes up a panel in the middle. It is easier to cross-rub the ends of panels; but this is not regarded as good form by many of the professionals. When the surface has been rubbed it is well washed, and the utmost care is required to have all the utensils for this service clean.

Cleanliness.—An entire extra set of sponges and chamois leather is kept for finishing up the washing, so that the surface at last may be as clean as possible. It goes without saying that all this work of varnishing and cleaning must be done in a room kept clean and free from dust. A varnishing-room should not contain shelves or anything to hold dust; it must be free from draft, and should be entered from a vestibule which has a second door opening into some other room; and the floor should be higher than that of the adjacent room, so that there will be a step up, which helps to keep out the dust which naturally lies on the floor. Nine-tenths of the trouble which varnish-users encounter comes from dirty and badly contrived rooms. Every varnish-maker is a victim of innumerable instances of this. The fault of the location is attributed to the varnish, and the user is intolerant of criticism. It is seldom of any use to tell a man that his trouble is due to his own deficiencies, whether personal or of his surroundings. He wants something which will compensate for those things; he doesn't get it.

Finishing-varnish.—The finishing-varnish, which contains about 25 gals. of oil to 100 lbs. of the best hard varnish-resins, and is of all varnishes the most exacting and the most difficult to make, is in this country often called "wearing-body" varnish. It is at once brilliant, hard, elastic, and durable. This is the kind of a varnish which the great painters of the middle ages were trying to make. Kept indoors, as works of art are, it would last a very long time. It is not the most durable varnish that can be made, but is the most durable brilliant varnish. Containing a large proportion of oil its flowing qualities are second only to that of oil itself; and it is applied as a heavy flowing coat with a large, thick brush of the finest hair. Like every difficult operation of art it is only to be learned by observation and practice. It is the finish and crown of all the work which has gone before.

Keep the Carriage Warm, Dry, and Clean.—When it is done the structure is left at rest in a dry, warm, clean room for a day; then it is dry enough so that dust will not stick to it easily, and it may be removed to another dry, warm, clean room to remain until it is thoroughly dry and hard. Varnish, while drying, must always be kept warm, and of an even temperature, not exposed to sudden changes of any sort, and dry as well as clean. A damp atmosphere, sometimes unavoidable because of the climate, is a fruitful source of trouble. Dirt and dust are the great adversary, and there is no peace in this life for the varnish-user who cannot overcome them. When one reads of the Chinese and Japanese lacquers which harden in rooms with wet floors and the walls hung with wet sheets he is moved to envy. The heathen Chinee certainly does accomplish wonderful things in this, and perhaps we may have to learn from him; though it is believed by many that there are just as great heathen engaged in the varnish business in this country as there are anywhere.

Shorter Methods.—It is not here asserted that every grocer's delivery wagon is finished with the elaborate detail which has been described. There are many short cuts to economy. For instance, it is very common to omit the use of rough-stuff. The work is primed, given a coat of rub-lead (which may be tinted the color of the paint which is to follow), sandpapered, painted, and given a coat, not of rubbing-varnish, but of finishing-varnish; and good durable varnishes are made at a less cost than wearing-body. Such a finish is not as smooth or brilliant as a more costly one, but it may be reasonably durable. Rough-stuff is very commonly omitted on the running-gear of carriages, especially on the wheels, as being too hard and possibly brittle. The running-gear is made up of pieces with curved surfaces. These are much more shiny than flat ones, hence require less work to make them look well. Gears are usually finished with a darker, and therefore cheaper varnish than that used on the carriage-body. There is no limit to the ingenuity which has been displayed in inventing cheap ways to refinish wagons and still have them look well enough to be accepted by the owners. Even the railroad-coach painters can take lessons from the carriage men in this. As Denham's couplet has it:

> "They varnish all their errors, and secure
> The ills they act, and all the world endure."

But these things are out of place here. The aim of the foregoing sketch of the subject is to tell the uninstructed but interested inquirer the general methods employed by good workmen, the principles of which are common to all the high-class shops, whose works do praise them; and of whom we may say, with Shakespeare:

> "We'll put on those shall praise your excellence,
> And set a double varnish on the same."

CHAPTER XXII.

HOUSE-PAINTING.

THE most important branch of the art of painting is that which relates to the protection and decoration of houses, by far the greatest portion of which are built of wood, and those which are said to be of brick or stone are largely of wood, having wooden floors, doors, and door- and window-casings. Oil paints are almost universally used on the exterior woodwork, and very largely within. Varnishes are also used on the interior, and in the better class of houses enamel paints are used to a considerable extent. Ceilings sometimes receive an alleged decoration with fresco or distemper paints, but the less said about that the better. It is only palaces and very fine houses which should be decorated in fresco.

The vast majority of houses in this country are painted with white-lead paint or with a mixture of white lead and white zinc, either pure or extended with barytes (barium sulphate), asbestine, whiting, silica, or other less important sophistications. These latter are often called "inert" pigments, but, as has been already pointed out, there are no inert pigments. By an extension of courtesy they are sometimes called "auxiliary pigments"; they are added to cheapen the material, in some cases to make it softer, as when asbestine is added to zinc, and to make it less liable to settle in the package; they probably have some protective effect, but they serve chiefly to afford a profit to the maker or dealer; not primarily for the benefit of the consumer. The latter is not an object of unreserved pity; he uses a paint at a dollar or so per gallon because he is unwilling to pay a fair price for a more economical material, and this because of his ignorance. The makers of really good mixed paints suffer as much from this as the makers of white lead and white zinc do directly.

As nearly as the writer can estimate, about four times as much white lead as white zinc is used for painting; practically all the white lead made is used in this way, while white zinc is extensively used in other manufactures, especially in rubber; it is said that there are more pounds of white zinc in a rubber tire than of rubber itself. One part of white zinc is often added to two or three parts of white lead, to make a harder paint.

White Lead.—It is usually sold as "paste white lead," ground with 8 per cent. of linseed-oil, and when obtained in this form from the manufacturers of white lead (who are not usually makers of prepared paints) is always pure, so far as my experience goes. But there are many jobbers who sell adulterated white lead; paint has been sold in this country (and elsewhere) as pure white lead in pure linseed-oil which contained no white lead and no linseed-oil; hence, the buyer will do well to buy standard and guaranteed material, with a label on it which means something good and which will stand for a legal action. This applies likewise to buying white zinc, and varnish, and mixed paint; well, in fact, to everything, but especially to paints and varnishes.

White Zinc.—The manufacture of white zinc in this country is chiefly in the hands of the New Jersey Zinc Company, and it is obvious that its specifications for using it are entitled to a great weight. The following is the authorized discussion, by the experts of this company, of the principles involved; and the user is advised to use as a vehicle only pure raw linseed-oil, in amount not less than 31 per cent. of the weight of the completed liquid paint, with turpentine and drier not exceeding 5 per cent. of said weight. The exact proportions are left to the judgment and experience of the painter, or in the case of using prepared paints, of the manufacturer.

The pigments come under two classes, the "base" and the "tint." Both these terms are highly descriptive.

The base pigments give to the paint its "body" or consistency. On the proper selection of the base pigments depends to a very large extent the quality of the paint, whether considered from the point of view of its application by the painter, or its endurance and protective effect on the surface to which it is applied. The "hiding power," or capacity to conceal the surface over which the paint is applied; the spreading rate, or the area of surface over which it will extend in a continuous layer when applied with the brush; the protective power or power to protect the surface from atmospheric agencies of destruction; the class of surface produced, whether "flat" or "oil-paint" or "enamel"; these and many other valuable properties are to a very large extent controlled by the base-pigments.

Bearing these principles in mind, let us now consider the first specification, "woodwork exterior" paint in detail, beginning with the first formula.

	Alternative Formulæ, Per cent.				
Zinc Oxide	45	50	50	50	50
Basic Carbonate White Lead	20	20		35	50
Basic Sulphate White Lead	25	20	35		
Asbestine or Silex or Barium Sulphate	10	10	15	15	

We have here four pigments, zinc oxide, basic carbonate white lead, basic sulphate white lead and a choice of three others, namely, asbestine or silex or barium sulphate.

Zinc oxide is the best individual white pigment known. In whiteness, hiding power, permanence, durability, inertness to oil and protective power, it takes front rank. When exposed to air containing sulphur compounds which would darken or blacken white lead, it remains white, as the sulphide of zinc is as white as the oxide. It does not chalk or crumble, and it does not become transparent.

Then if this is the case, why not use zinc oxide alone in our paint? Why all the other constituents?

The answer is that zinc oxide, when used alone, has certain economic drawbacks which vanish entirely when it is used in a properly compounded mixed paint.

In the first place, owing to its excessive fineness, zinc oxide forms a perfect blend with the oil, and in consequence spreads out under the brush to an exceedingly thin layer. Hence, in order to get the thickness of paint coating necessary to cover and protect properly, more coats of paint are required, than say, with white lead. Now when we mix white lead and one or more of the three pigments, asbestine, silex or barium sulphate with the zinc oxide, we stop this tendency to excessive spreading. These pigments are, comparatively speaking, coarse-grained. They have what painters call "tooth." They take hold of the surface of the wood and cling there, and prevent the paint from spreading out too thin, and the necessary covering can be got with fewer coats of paint.

Secondly, a paint consisting of zinc oxide and linseed oil only, dries with a hard, smooth surface. The advantages of this we shall deal with later. The disadvantage is that when, in the course of years the oil becomes dry and decomposed (as happens sooner or later with all paints) the paint coat cracks and peels off in patches. This makes it impossible to do a good job of repainting unless the old paint is burnt off or otherwise removed. Now white lead does not do this. When a white lead paint coat fails, it does so by crumbling to powder, or as painters say, "chalking." The surface of a chalking paint gives an even surface for repainting.

Now when we make up a paint composed of zinc oxide, white lead and inert pigments, we get the advantages proper to each of the pigments. The zinc oxide imparts whiteness, durability and permanence of color; the inerts and white lead enable the painter to get a good covering layer of paint for each coat he applies, and the white lead insures that a good surface for repainting shall be present when in course of time the paint has perished.

And zinc oxide does one thing more. If we paint two boards, one with zinc oxide and one with white lead, and expose them to a dusty atmosphere, the white lead board will accumulate dust much faster than the zinc oxide board. The smooth, even surface of the latter makes it very difficult for the particles of dirt to adhere, whilst the comparatively rough surface of the former holds them. This is particularly well shown when a wet sponge is passed over the boards. The zinc board will show up clean and white after this treatment, whilst the lead board will remain dirty. A board painted with a mixed paint such as the specifications show, behaves in this respect like a board painted with straight zinc oxide. The zinc oxide, owing to its excessively fine state of division, blends so thoroughly with the oil, that it enters the glossy surface which the oil forms over the paint, so that the surface of the paint coat has the same dirt—and we may say also wet—repelling power that a straight zinc oxide paint possesses, and at the same time the mixture is free from the tendency to crack and peel and gives a good surface for repainting. The effect of this property on the protective value of the paint is obvious.

Hence in the specification paints we have a combination of the advantages which the different pigments possess, so blended that the pigments reinforce one another, and make, practically speaking, a better paint than any one of these could make alone.

As regards the two white leads, basic carbonate white lead and basic sulphate white lead, both are useful as insuring a good repainting surface. Basic sulphate white lead is a very fine-grained pigment, and paints made from a mixture of zinc oxide and basic sulphate white lead require the presence of one of the coarser pigments to regulate the spreading. When basic carbonate white lead is used, this is not necessary, as this pigment supplies the necessary " tooth."

It will be noticed that 15 per cent. is specified for " inert " pigments. These are too transparent and too coarse-grained to be used in large amount, but in moderate percentages are useful as conferring " tooth."

Turning now to the vehicle, all paint grinders are agreed that there is no vehicle that can equal, much less surpass, good linseed-oil for exterior work. To this a little dryer and turpentine should be added, as without them the paint dries too slowly and contamination of the wet surface by dust, insects, etc., or injury by rain is liable to occur. The iodine value (Hanus method) is a useful method of checking the purity of the oil, and a minimum figure of 175 should be insisted on. This is a somewhat technical matter and lies strictly within the province of the paint chemist, but good paint grinders are keenly alive to the necessity of using only first-class oil in their paints and are very careful about testing.

It may be said, in addition to this, that in Europe there has been much agitation, originated apparently by the manufacturers of white zinc, for legislation prohibiting the use of white lead, on the alleged ground that it causes lead-poisoning among the workmen, but it is noticeable that the workmen themselves almost unanimously oppose such legislation. This brings up the problem of painting with zinc alone; and M. Paul Fleury appears to be the best informed writer on the subject, and also to have practical experience; he advises the following formulas:

For exterior painting, on woodwork:

First coat	100	parts (by weight)	white zinc in oil (paste).
	31	" "	linseed-oil.
	21	" "	turpentine.
	2½	" "	drier.
Second coat	100	parts	white zinc paste.
	20	"	linseed-oil.
	10	"	turpentine.
	3	"	drier.
Third coat	100	parts	white zinc paste.
	23	"	linseed-oil.
	3½	"	drier.

For outside plastered walls:

First coat	100	parts	white zinc paste.
	93	"	linseed-oil.
	2½	"	drier.
Second coat	100	parts	white zinc paste.
	70	"	linseed-oil.
	3	"	drier.
Third coat	100	parts	white zinc paste.
	47	"	linseed-oil.
	3	"	drier.

Paste filler for wood:

100	parts	white zinc paste.
10	"	linseed-oil.
12	"	turpentine.
3	"	drier.

It appears to be a frequent practice in Europe to apply a filler of the general character of the last formula, whether of zinc or lead, and when dry this is lightly sandpapered; the sandpapering of this filler is the most common cause of lead-poisoning. This is never done in this country. Our system of painting gives good results; perhaps not as fine a finish, but probably more durability, and with much less expense. It is, moreover, believed by our best painters that on even the most expensive sort of work silica makes a better filler than anything else; some lead is sometimes mixed with it. The white zinc paste of Fleury contains 85 per cent. dry white zinc and 15 per cent. linseed-oil.

Fleury, however, agrees with the New Jersey Company that white zinc alone is not as durable nor as easily worked with the brush as white lead or mixtures containing a large proportion of the latter. He says that as compared to lead the workman must take more care with zinc, will do less in a day, and the result is not likely to be as good; and that five coats, or at least four, must be used where three of lead would be ample; this latter because white zinc paint has only about half as much pigment per gallon as lead.

On the other hand the makers of white lead stoutly maintain that theirs is a complete pigment, and that anything added to it, except for tinting, makes it less valuable. It is practically always sold in paste form, containing 8 per cent. of oil; the unit is 100 pounds, which measures 2.8 gallons, and is put up in a strong steel package.

The National Lead Company advise that for new work, outside (wood) there should be used for:

First coat	100 pounds white lead paste.
	4 gallons (31 pounds) raw linseed-oil.
	2 gallons (14⅓ pounds) turpentine.
	1 pint (1 pound) drier.
	9 gallons, for one coat on 5175 sq. ft.
Second coat	100 pounds white lead paste.
	1½ gallons (11⅝ pounds) raw linseed-oil.
	1½ gallons (10⅘ pounds) turpentine.
	1 pint (1 pound) drier.
	6 gallons for one coat on 3600 sq. ft.
Third coat	100 pounds white lead paste.
	3½ to 4½ gallons raw linseed-oil.
	1 pint turpentine.
	1 pint drier.
	7 gallons for one coat on 4200 sq. ft.

For inside work about one-quarter less oil would be used in first and third coats; and for repainting old work, outside or inside, half the amount of oil for the first coat.

It will be noted that considerable spirit of turpentine is used, especially in the first coat; this is because it penetrates the wood, especially if at all pitchy, much better than oil, and it thins the paint without increasing the proportion of oil in the dried film; that is, it makes the film harder than it would be if the vehicle were all oil. It is not used with white zinc, because the dried film of white zinc and oil is hard enough even with all the oil it contains.

Turpentine is a much more mobile fluid than oil, that is, it has less viscosity and a gallon of it thins a mixture about as much as 2 gallons of oil. So a paint containing much turpentine is very thin and spreads over much surface; but on the other hand the oil and turpentine in a priming coat on new wood sinks into the wood rapidly, which lessens the spreading power. The theory of using a large proportion of oil in the priming coat is that the oil is needed to fill the pores of the wood, and that if but little oil is used the wood will absorb it, leaving the pigment without enough binder.

But there is another theory, and another practice. It has been explained how the carriage-painter builds a hard, unyielding foundation to cover with paint and varnish, on the theory that successive coats should be each more elastic than its immediate foundation, and that an elastic foundation is to be avoided. So a man trained in such work applies a first coat, in house-painting, of lead thinned with little oil and much turpentine, believing that the affinity between the oil and the lead will prevent the oil from going into the wood much, and he puts on a thin hard coat for a base. The second coat has more oil and less turpentine, and the third or finishing coat is like the one already given. The writer has seen hundreds of houses painted in this way, and they certainly looked well and the paint was durable; it was hard, and, wonderful to tell, it did not chalk. There is no question but that any sound theory of painting calls for each successive coat to be more and more elastic; the sun and weather hardens the surface, and the further from the surface the less is this effect.

The formulas given call for raw linseed-oil and drier. If preferred, the oil may be half boiled oil and half raw, and the driers omitted or decreased. If a drier is used it should be pale in color, and free from rosin. The latter is not an easy thing to detect, but if a fair price is paid, say $1.50 to $2 a gallon at retail, and freedom from rosin is guaranteed by a maker of good reputation, the buyer ought to be safe. For the benefit of the maker of paints it may be said that such driers are made usually of oil, combined with much lead and a little manganese. Japan driers containing resins (not rosin) are also excellent, but their price is high if they are of good quality. There are some low-temperature manganese driers which have a good name, but the black or very dark japan driers are to be avoided, for they injure the durability of the paint. Every bit of drier you use is a damage to you, and the lack of it is fatal, for the paint certainly must dry in a reasonable time.

Dark Colors Most Durable.—Paints made with white lead and white zinc as a basis are good paints, but there are more durable paints (for wood) made of other pigments. The ochres, umber, sienna, and the iron oxides in general are far more permanent, and to paints the color of which will admit the use of an appreciable amount of lampblack this latter pigment imparts a high degree of stability. There is no paint so lasting on wood as black paint made with lampblack as the coloring-matter. A great variety of subdued yellows, browns, and reds may be made which will outlast the lead or zinc paints. Sometimes, where the final color can only be had by one of the latter, the priming-coat and the second may be of the former with advantage. They are also cheaper. Lead and zinc are expensive pigments, and a white-lead paint weighs 20 lbs. to the gallon when ready for use, while oxides weigh about 12 lbs. per gallon.

Knots.—Pine wood usually contains knots, some of which are full of pitch, and this pitch will penetrate any oil paint or oleo-resinous varnish and make a bad spot. These knots may be covered with shellac varnish, on which the pitch does not act, before painting. Some of the liquids distilled from pine wood, of which many are on the market, are also said to be efficient for this purpose. Some woods, southern pine in particular, are very bad to paint because of the pitch they contain, which makes the paint peel off; and this should be remembered when passing judgment on a job of painting which has not lasted well. If shellac is used for stopping knots it is common to use white shellac if a very light paint is to be used over it; but if the paint is dark use orange shellac because it is a better varnish than white shellac. The latter must be used if the wood is to be finished in the natural colors with varnish.

Priming-coat.—If a coat of good thick paint is applied to a fresh surface of wood the oil is absorbed, leaving the pigment without enough binding material. For this reason it is proper to first prepare the surface of the wood before the paint is applied.

This is called filling the surface; in reality it is filling the pores, and the material used is called a filler. The best filler for wood which is to receive ordinary oil paint is a coat of pure raw linseed-oil. After this has disappeared in the wood a coat of very thin paint may be applied. Sometimes this second coat is also pure oil, but if pigment is added very little should be used.

Putty.—After the wood is thus filled, or primed, is the time to putty up all nail-holes and other defective places. Putty is made of whiting, which is ground chalk, to 100 pounds of which is added 18 pounds raw linseed-oil, and the whole well mixed, making a plastic mass. Ordinary whiting makes better putty than the higher-priced "gilders' whiting." White lead putty contains only about a third as much oil as this, and for some purposes 10 per cent. of it is mixed with common putty. Pure white lead putty is sometimes used for cracks, and other special uses. Marble dust takes only 6 or 7 per cent. of oil, hence is much cheaper for putty; but is perfectly worthless. Mud would be quite as good. On outside painted work it is perhaps allowable to apply putty with a steel putty-knife; but on interior work a wooden stick or spatula must be used, so as not to mar the surface. Putty should never be applied to the natural surface of the wood, since that would absorb part of the oil and leave the putty dry and friable; the wood must first be primed.

The surface is now ready to be painted, and should receive at least two good coats of paint, sufficient time to dry being allowed between coats. If the window-casings and other raised surfaces are to be painted a different color from the body of the house, it is well to do this first; the body-color may then be laid neatly up to the other. It is a good plan to paint the back or interior surface of all window and door-casings before they are erected with a cheap oxide paint, made with pure linseed-oil; this will prevent warping and distortion. This is not commonly done except on fine houses, but it is desirable.

Area Covered.—A gallon of paint will cover 400 to 600 sq. ft.; white lead covers more than other white paints, but not more than browns and other dark colors. Some prepared paints cover not more than 300 sq. ft. Paint can be too thin; also too thick to dry well.

The foregoing directions apply to the most common sort of exterior painting. Nothing has been said about the use of varnish in paint for this purpose, but in fact the best makers of house-paints are large buyers of varnish, the addition of which increases the durability and improves the appearance of the paint. It makes it glossy, so that dirt does not so easily adhere to it. If varnish is used for this purpose it ought to be good varnish, and this will increase the cost of the paint.

Interior Woodwork.—The treatment of the interior woodwork is much more complicated. It should be thoroughly seasoned and dry before any finishing is done, and should be sandpapered to an even surface, all sandpapering to be done with the grain of the wood. As recommended for window- and door-casings, the back of all interior woodwork must be thoroughly painted with a good, durable linseed-oil paint, thin enough to serve as a priming-coat. This must be done immediately after the pieces are delivered on the premises. The first coat of filler must also be applied to the front or outer surface. In this way the absorption of moisture will be prevented; and all this should be done before the work has been allowed to remain overnight on the premises. This may seem somewhat exacting, but we should remember that neglect of this precaution may impair the value of the material during its whole service. The most important of all things is to start right. The first coat of filler is usually linseed-oil, and this may be applied very rapidly.

Fillers.—There are two sorts of fillers made: liquid fillers and paste fillers. The former are commonly rosin compounds, and never should be used for any purpose. If a liquid filler must be used, fill the wood completely with raw or boiled linseed-oil, or with a good varnish. The very best filler that can ever be put on wood is a good varnish; but this is not what is commonly meant by a filler. Paste fillers are a sort of paint; the best have pulverized quartz as the solid part, corresponding to the pigment, and the liquid is a quick-drying varnish. Only enough liquid is used to make a sort of paste, and before applying this is mixed with spirit of turpentine to such a consistency that it can be applied with a short, stiff bristle brush, and it must be rubbed well into the pores of the wood. In about half an hour it will be found to have set, and the excess must then be rubbed off clean, first with excelsior (fibrous wood-shavings) and then with felt, rubbing across the grain of the wood so as to force the filler into the pores. It is practically impossible for the amateur to make as good a filler as he can buy. The pigment must be ground fine, yet it should not be so fine as to have too little grit, and the mixing of a varnish to have just the right properties is a difficult matter. No better advice is possible to any one desiring to experiment in this direction than to get the best paste filler on the market and try to match it. Wood-fillers may be, and usually are, stained by the addition of oil-stains to the color of the wood, or to the color desired by the designer. This is done when they are finally thinned before using. These oil-stains are really paints made with selected pigments of extraordinary fineness, and may be added to or thinned with oil, varnish, or turpentine. Such pigments are used as are somewhat transparent but have a deep and brilliant color; great staining-power, but not great opacity. Raw (unroasted) sienna may be regarded as a typical pigment of this class.

The practice of filling wood completely with varnish has been recommended. It is a very old method. It is natural that those who do this should wish to use a cheaper varnish for this use than that with which they finish; also that they should want a varnish which will dry quickly. The combination of these qualities, carried to the extreme, results in a rosin varnish loaded with driers; and this is what is meant now, in the trade, by a liquid filler. Rosin, with little oil, requires very little turpentine or benzine to make it a thin liquid; in fact pale rosin is almost a liquid already, so that a varnish of this sort has very little volatile matter in it and consequently fills up the pores of the wood very quickly, and dries almost as a spirit varnish does by the evaporation of the solvent. But no good ought to come to the man who puts such a compound on a piece of wood which is afterward to be varnished with decent material.

A good paste filler, on the other hand, has just as much solid matter in it as possible, and what cementing material there is may be of first-rate quality. There is so little of it anyway that it is not expensive to have it good.

Object of Filling.—The object in using a paste filler is to fill the pores of the wood with solid matter, so that the surface to be varnished shall be without any soft and absorbent places, but hard and glassy. The filler is rubbed into the wood when it is applied, and when it has hardened it is rubbed so that all that can be crowded into the wood may remain, and the surplus be taken off. This is also the way furniture is treated; but rubbing-varnishes are then sometimes used on furniture, while they should not be used on the woodwork of houses, which should be varnished with at least three coats of a moderately elastic varnish, made with 20 gals. of oil to 100 lbs. of resin. Not less than a week should elapse between coats. It is best to sandpaper the first coat with very fine sandpaper, and the second coat, when dry, should be rubbed with curled hair until the gloss is removed. These precautions secure a more perfect union between the different coats, and a more perfect surface. After the last coat has become quite hard, if the glossy surface is not liked, it may be rubbed with powdered pumice and water, with a piece of thick felt, until the gloss is removed. Four coats of varnish are better than three, and if a wood-filler has not been used four coats are necessary.

Exterior Varnished Work.—Exterior woodwork, such as outside doors, railings, and the like should never receive any filler, which lessens the durability of the varnish, but should be treated with not less than four coats of spar varnish or a varnish made on the same lines as spar; that is, the wood should be both filled and varnished with the same material. There is no objection to a preliminary coat of oil, which should have plenty of time to dry. Usually it is most convenient to apply oil for the preliminary coat, which is to hinder the hygroscopic action of the wood, and is put on before or immediately after the woodwork has been brought on the premises; and all inside blinds, window-sills, and jambs, in fact everything exposed to the direct rays of the sun, must be treated as exterior woodwork. Outside blinds are painted with the same kind of paint, though not the same color, as the outside of the house.

Interior Enamel Painting.—If any of the interior woodwork is to be finished in white enamel paint (or any light-colored enamel), it should be well painted with pure white lead and linseed-oil. This should be done according to the directions for outside work. It is allowable, however, to add some spirit of turpentine instead of all oil, as this makes the paint dry more quickly, and on interior work will be sufficiently durable. Two coats of white enamel paint are to be applied for a finish. The question may arise, why not do all the painting with enamel paint? Because the oil paint contains more pigment and less vehicle, and hence is much more opaque than enamel. It is cheaper by the gallon, very much cheaper in labor, far more rapid, and is good enough. Two coats of an enamel paint applied to a good white under-coat, which should consist of a priming-coat and two full coats, will give a beautiful surface. The first of these enamel coats should be rubbed with curled hair, and the second may be finished to suit the owner.

Floors.—Floors are a source of endless trouble. Soft-wood floors are sometimes painted, and this is easy, for when the paint wears off it can be renewed. Some soft-wood floors are stained. The best way to do this is to thin down an oil-stain with spirit of turpentine and color it. The stain sinks into the wood and cannot be removed, except as the wood wears off. The floor can then be varnished. If it has already been filled with varnish the stain cannot get in; then the easiest way is to add some oil-stain to a floor varnish and apply it. Hard-wood floors are not stained, but are varnished to show the natural color of the wood, and look very fine when new, but the soles and especially the nail-clad heels of shoes will wear the varnish off after a little; not all over the floor but near doors and wherever people continually pass. The margins of the floor are all right but the worn places look badly, and if not attended to, dirt gets into the grain of the wood and can hardly be removed. If these places are revarnished and the rest of the floor left untouched a spotty appearance is produced; but the owner may be consoled by finding that if the varnish is rubbed out thin around the edges of the newly varnished places it does not show so much, and after a week or two is not at all conspicuous; and in the judgment of the writer this is better than to pile up varnish on those parts of the surface which do not need it. The art of varnishing a floor is not very difficult, and there ought always to be some one about a house with energy enough to do such work in case of emergency. A good floor varnish dries rapidly. If a thin coat is put on at night it is hard enough to use next day. White shellac varnish is very often used on floors, chiefly because it dries almost immediately. It is in fact a very good floor varnish; but it is not nearly as durable as a good oleo-resinous varnish, and the chief trouble about floors is that the best varnish is short-lived. Factory floors are sometimes covered with galvanized sheet iron, and this wears out after a time; so it must surprise no one to have a coating of varnish wear off, especially as it is only a tenth part as thick as the sheet iron. We must not expect to walk continuously for many months on a layer of anything which is only two or three thousandths of an inch in thickness.

A filler should never be used on a floor, which should be thoroughly saturated with oil and varnish. The latter should be fairly hard; as it is not exposed to the weather it is not likely to crack, and a soft varnish does not wear as well as a hard one. It may contain 12 to 18 gals. of oil to 100 lbs. of resin. Less oil makes it brittle; more makes it soft. It would probably be a good plan to use a good varnish-remover once in five or six years and take off all the paint and varnish from a floor and begin anew. Since the improvements in these preparations, paint and varnish can be easily removed without the danger of fire which attends the use of a gasoline torch in a furnished house.

Floor Wax.—There is still another way to treat a floor, which is by the use of wax. The wax is made into a paste with spirit of turpentine and the floor is thoroughly filled with it. This is a rather laborious job and takes some time. The brushes used for rubbing in and polishing the wax are large and stiff. They are weighted with heavy iron backs and are attached to a long handle. The floor ought to be polished with this brush daily, and twice a month a little fresh wax should be added. A properly kept waxed floor is very handsome. It looks rather better than a well-varnished one, but it requires a great deal of attention, and if neglected nothing can look worse; and after a floor has been well waxed it is difficult, some think impossible, to wash it out so that it will take varnish. A waxed floor in good condition is also very slippery, sometimes almost dangerously so; rugs slide around on it like boards on ice. But it certainly is a beautiful finish, and protects the wood; and the necessity of keeping it rewaxed, if it is to look well, makes it necessary to do it by domestic labor, and this tends to keep the floor in condition. It is rather hard work to use the polishing-brush efficiently.

The wax used is not commonly beeswax, but a vegetable wax called carnauba wax, harder than beeswax. Floorwax is not a simple substance, but the best preparations are apparently rather complex; each maker has his own formula. Beeswax is sometimes used; but the carnauba-wax mixtures are less sticky, and much superior to it in every way. Printed directions are furnished by the makers, and may be carried out by any one of ordinary intelligence. Wax finishes are sometimes, though rarely, used on interior woodwork, but not on stair-rails, nor on furniture. They can be applied to floors which have been varnished, if the varnish has worn or been scrubbed off. The fact that the wood is filled with varnish is no objection. In fact the directions for using wax usually advise filling the wood before waxing.

Metal Roofs and Gutters.—Tin roofs and metal gutters and leaders have been a source of trouble from time immemorial. The painter's tradition is that tin roofs cannot be painted until they have stood long enough to become rusty; then the paint will adhere. This is "flat burglary as ever was committed." It is true that paint does not adhere well to new tin. The reason is that new tin is greasy, or covered with some chemical substances which are inimical to paint. Tin plate, it is well known, is made from thin iron plates (called "black plates") by dipping them in a bath of melted tin; in the same way galvanized iron is made by dipping iron in melted zinc. But the melted metal will not adhere to the iron unless the latter is chemically clean. This is effected by dipping it in acid, from which it goes to the bath of hot metal. A little acid is in this way carried over, and thus is formed a film of chloride or sulphate of tin or zinc, which, in an anhydrous and melted condition, floats on top of the bath, and as the coated plates emerge, a little of this compound sticks to them. This is powerfully corrosive, and will destroy any paint. Another trouble is caused by the practice some makers have of covering the melted metal with hot oil, usually palm-oil, to prevent the air from getting at it; and as the plates come through they get a final coating of hot oil. Still another practice is that of hanging the coated tin plates in hot oil to drain. In some of these ways nearly all tin and galvanized iron is coated with something which prevents the adhesion of paint. The remedy is obvious. Clean the roof before you paint it. It ought to be thoroughly scrubbed with soap and water. Some rub the metal well with coarse cloths, such as burlap, well wet with benzine. If soap and water are used, the scrubbing should be followed by a thorough rinsing with clean water, and of course the roof should be dry when painted. By following these directions, tinned and galvanized metal-work may be painted; and aside from these directions the methods and materials employed on structural steel should be used. It is a wise, though not very usual, practice to paint the lower side of the tin before laying it on the roof. This should be a coat of very heavy and good paint. This prevents corrosion from below. New metal roofs should receive three coats of a highly elastic varnish or paint; probably four would be economical, for they will almost certainly be neglected. They are exposed to very severe conditions, and a varnish or paint too elastic or soft to be used almost anywhere else will grow hard under the heat and intense chemical action of the rays of the sun. There are plenty of compositions sold for painting these surfaces, the secret of which lies in following directions essentially like those just given, by which any good paint may be made to adhere. They are like the drugs which are sold to cure the tobacco habit, which will certainly cure if taken according to directions, one of which is that the patient shall abstain from the use of tobacco for a term of some years; so if these metal paints are used strictly as prescribed they will stick. No doubt they will, if they are good for anything.

Fire-proof Paints.—Shingled roofs are sometimes painted with what are called fire-proof paints. No paint is really fire-proof, but it may be made to retard the spread of fire. If a roof is painted with something which will prevent its being set on fire by a burning fragment carried by the wind from some other building, it must be conceded that a substantial gain has been secured, and this can probably be effected. In the first place it must be remembered that any oil or varnish is in its original condition highly combustible; that combustion is a process of oxidation; that oil and varnish dry by oxidation, and hence that when they are thoroughly dry they are far less easily set on fire than when fresh; hence it is not fair to test a fire-proof paint until it is thoroughly dry. Any good paint may be made more resistant to fire by adding to each gallon of it ¾ lb. or 1 lb. of boric (boracic) acid. This is a solid substance which is purchased in the form of a powder or flakes. When subjected to heat this fuses and forms a sort of glass, and this protects the wood from the access of air; also it is slowly converted into vapor, and this forms a protective coating over the roof, for if the air cannot get to the wood the latter may be heated so as to char, but it will not burn, and this is just what takes place. Some of the patented paints contain instead of boric acid some very easily fusible glass, powdered. The glass melts with the heat and protects the wood. Ordinary glass will not answer; and this extra-fusible glass is open to the same objection as boric acid, in that it is soluble in water and gradually is washed out by the rain; but, of course, in all cases the oil or varnish in the paint keeps the rain from the soluble constituents for a considerable time. Such paints must therefore be renewed rather frequently.

Sanding.—When paint is partly dry, but while it is still tacky, it is sometimes sanded. This is done by sprinkling dry sand over its surface. The effect of this is to make a rough, hard surface somewhat resembling stone in appearance. It does not appear to be generally known that any dry pigment may be mixed with the dry sand, by tumbling them together in a revolving barrel or by any equivalent means; by doing so the grains of sand receive a film of dry paint, and when applied to the painted surface an effect is produced which is sometimes much better than can be had by the use of sand alone. A black varnish, for instance, can be thus made brown, olive, dark green, or almost any dark color. If desired, a sanded coat, when thoroughly dry, may receive a very thin coat of paint and be sanded again. In this way a very rough surface is produced. The influence of the sand in resisting abrasion is considerable. Metal gutters and leaders on stone buildings can be painted to match the color of the stone and then sanded, when they are much less conspicuous than if treated in any other way.

Cellars are usually whitewashed. Whitewash is better and more sanitary than calcimine; and casein paints are not suitable for damp and dark places.

Plastered walls are often painted. These should be allowed to stand a year before painting if possible; this is to get rid of caustic alkali. They may then be painted with any oil or varnish paint. Many preparations are recommended for preparing fresh plaster for painting; saturated alum solution, followed by soap solution, is an old treatment; the best the writer has seen is a varnish made very thin, and containing a considerable proportion of tung-oil.

In general it may be said that thin coats of paint or varnish, well brushed out, are more durable than an equal amount of material applied in heavy coats, and are not so liable to crack; that varnishes and enamel paints should always be rubbed between coats with curled hair or fine sandpaper to remove the gloss, for if this is not done the succeeding coat does not adhere properly; and that on exterior work the last coat of varnish or enamel should be left with the full gloss, as its durability is impaired by removing the gloss from the last coat. There are three sorts of finish for interior varnished or enamelled surfaces, the first being the least and the last the most expensive: they may be left with a full, natural gloss; they may be rubbed to a dull finish with curled hair, very fine sandpaper, or pumice and water; or they may be first pumiced and then given a high polish with rottenstone and water.

Above all things, use good material. A good varnish may be had for $3 a gallon at retail, and will give a finish that with moderately good care will last many years; while a cheap varnish sold for $1.50 or $2 will lose its lustre in a short time and will be a positive eyesore in a year or two. The former, even if it cost $15 a gallon, would be cheaper than the latter. There are legitimate and proper uses for cheap varnishes; but it is a shameful thing to put them on a house which people have got to live in and look at, and which is intended to last for generations. Not only is the appearance of such things poor, but they do not protect the surface, which gets full of dirt and germs of all sorts. A good varnish or paint is one of the best aids to cleanliness and purity of which we can avail ourselves.

Putty for Windows.—The use of white-lead putty has been recommended for filling cracks. Carriage-makers mix a little japan with this to make it dry quickly, and this may perhaps be permitted, though not recommended, for interior work, but not for exterior use; but white-lead putty is not advised for setting glass, because it is so difficult to remove when the glass is broken and must be renewed. Regular putty is made by working pure linseed-oil and whiting, which is ground chalk, together until of the proper consistency. It is applied in a plastic condition, but rapidly sets and finally becomes hard and is very durable. But the reader is advised that pure putty is only to be obtained with great difficulty. It is adulterated, or rather a spurious substitute is made, by the use of marble-dust instead of whiting. Marble-dust is granular and harsh, whiting is soft and smooth; and the oil is adulterated with or entirely substituted by some cheap mineral oil or rosin mixture. If pure putty is used the amount used on an ordinary house probably does not amount to $1; yet the use of an inferior article, the removal and replacement of which will cost from 50 cents to $1 per window, probably gives a profit to the contractor of 25 to 50 cents on the whole house. The contractor should be required to guarantee the putty for two years, and of the money due him at least $1 a window should remain unpaid until the guarantee has expired. The real reason for this very common and inexcusable adulteration is that sash are not hand-made, but factory made, and are commonly supplied ready glazed, so that the sash-maker is the man who buys the putty, and he buys it in ton lots. Instead of paying say $60 a ton he buys it for $30, and thus makes $30. To secure this he gets bad material, really much worse than none, on fifty houses, at a final cost to the ultimate purchasers of $1,000 or $2,000 in the aggregate. The only remedy is in requiring a guarantee, which the contractor may in turn require from the sash-maker. There is absolutely no risk to him if he uses straight goods. If this practice were generally adopted the manufacture of adulterated putty would immediately cease. Putty is made by machinery; but not necessarily, for any one can make it with no other apparatus than his hands, and while hand-made putty is costly as compared with the other, $3 or $4 worth of labor would make all the putty needed for an average house; so there is no excuse for using an inferior article.

Burning-off.—Painted woodwork, and especially painted outside doors, sometimes require the entire removal of the old paint before repainting. The regular way to do this is by "burning-off." This does not mean that the paint is actually burned. If this were done the wood would be charred and injured. It is done by the aid of a painter's torch, burning kerosene or naphtha, by which a flaring flame is directed against the painted surface. The operator holds the torch in one hand and a broad-bladed putty-knife in the other. The heat softens the old paint and with the putty-knife or scraper he scrapes it off. The paint is not burned at all but softened and loosened by heat.

Paint-removers.—Many preparations have been tried for removing old paint and varnish by chemical action, but these have never been liked because the solution, which has contained water and alkali, gets into the wood and unfits it for recoating; but lately a new sort of paint- and varnish-removers have come on the market. Containing no water and no alkali, they are composed of wood-alcohol and other alcohols, benzole, and various other liquids, mixed together, and are very efficient. When their work is done the surface may be washed off with benzine and is ready for repainting or varnishing. Many of the varnish-manufacturers are now selling compounds of this nature. They are applied with less risk and labor than are involved in burning-off. Of course they only soften the old coat, which must then be scraped off in the usual way.

STANDARD DEFINITIONS OF TERMS USED IN PAINT SPECIFICATIONS.

The following definitions of terms used in paint specifications were adopted in 1915 by the American Society for Testing Materials, after a consideration and discussion by a committee of producers and users of paint, which had been going on for several years; the report of the committee was finally unanimous, as was the society vote.

These definitions are not supposed to be the only ones for these words which should appear in a dictionary; but it is believed that they are good and accurate ones for the purpose. For example, those for "crystallin" and "amorphous" differ from those in general use; but if we consider substances like white lead and white zinc, which are always regarded as amorphous, we find that the most recent microscopical investigations appear to show that the minute particles of these substances have crystallin structure, as appears by their behavior to polarized light. On the other hand, the presence of normal lead carbonates in white lead is easily seen by the ordinary observer, as definitely shaped crystals; while the basic carbonate appears to him to be amorphous. From the consideration of many such cases it appears that these definitions provide a simple and useful means of reaching decisions which will be fair to all parties, and practically conform to usage; though it is not disputed that to a physical chemist other definitions may be necessary. A word is useful in proportion as it is easily and definitely understood; but that is no reason why in describing a locality one may not speak of a neighboring forest, with an essentially different meaning of the word than in saying that the Samaritan was a neighbor to the man by the wayside, or the Americans to the Belgians in the time of the war in Europe.

In fact, these definitions are in a sense authoritative, and were agreed to after prolonged discussion by many men of acute minds and ripe experience and scholarship; the utility of having them must outweigh captious or finical objections.

Standard.—Materials, methods, qualities, properties, etc., set forth by specifications as a basis for the measurement of requirements.

Equal to.—The use of this term should be avoided if possible. The avoidance of this term is recommended wherever possible because the specifications themselves should state the qualities, etc., desired. In specifications having the sanction of the American Society for Testing Materials, it is to be assumed that this feature will be developed to its fullest extent.

Pure.—The use of this term should be avoided if possible. The avoidance of this term is recommended wherever possible because it involves the acceptance of standards likely to cause dispute, whereas specifications having the sanction of the American Society for Testing Materials should involve the establishment of their own standards.

Adulteration.—The partial substitution of one substance for another without acknowledgment. The addition of the words "without acknowledgment" makes this definition clear. Substitution with acknowledgment involves no improper motive. If it is done without acknowledgment an improper motive may be assumed.

Adulterant.—A substance substituted partially for another without acknowledgment.

Bulk.—The bulk of a pigment is the total volume thereof plus voids. In referring to the bulk of a substance, it is often convenient to say: "Its bulk is (say) 10 grams to the cubic inch." In this case the word bulk is synonymous with "apparent density" and involves a determination by a specific method.

Voids.—The spaces between the particles of a pigment.

Opacity.—The degree of obstruction to the transmission of visible light. In this sense "opacity" is a relative term, it being considered that, given a film sufficiently thin, in paint technology at least, there is no absolutely opaque substance.

Covering Power.—The use of this term should be avoided if possible. This term has been used so loosely that it might mean hiding power, spreading power, or the simple property of producing a coat.

Hiding Power.—The power of a paint or paint material as used to obscure a surface painted with it. In this definition the word "obscure" means to render invisible or to cover up a surface so that it cannot be seen.

Spreading Rate.—The rate at which a paint or paint material as used, is brushed out to a continuous uniform film expressed in terms of the area to which a unit volume, as used, is applied. This term must not be confused with the much-abused term "spreading power." The use of the term "spreading rate" is illustrated in the following sentence: "The paint when spread on a planished iron surface at the rate of 600 sq. ft. to the gallon will not sag or run when placed in a vertical position at 70° F."

Fineness.—A term used to denote the extent of sub-division and expressive of the number of particles of pigment in a unit volume exclusive of voids. According to this definition, if pigment *A* has a specific gravity of 6 and pigment *B* a specific gravity of 2, and if these two pigments have equal fineness, in 6 grams of pigment *A* there would be the same number of particles as in 2 grams of pigment *B*.

Crystallin.—Having a definite structure referable to one of the crystallographic systems. According to definition a material is not crystallin if it has not a crystallin form irrespective of the optical and other properties it may possess.

Amorphous.—Without regular or definite form. This definition as given here has a broader meaning than it possesses when it is used in mineralogical writings. Protozoa, if of definite form, are not amorphous and may not be crystallin.

Paint.—A mixture of pigment with vehicle, intended to be spread in thin coats for decoration or protection, or both. According to this definition a mixture of pigment and varnish is a paint, and on the other hand a solution of stains in oil or varnish, no pigment being present, is not a paint.

Pigment.—The fine solid particles used in the preparation of paint, and substantially insoluble in the vehicle. Asphaltic materials are not pigments except when they contain substances substantially insoluble in the vehicle in which they are used.

Vehicle.—The liquid portion of a paint. Here anything that is dissolved in the liquid portion of a paint is a part of the vehicle.

Volatile Thinner.—All that liquid portion of a paint, water excepted, which is volatile in a current of steam at atmospheric pressure.

Non-volatile Vehicle.—The liquid portion of a paint excepting its volatile thinner and water.

Tinting Strength.—The power of coloring a given quantity of paint or pigment selected as a medium standard for estimating such power.

Color.—A generic term referring inclusively to all of the colors of the spectrum, white and black, and all tints, shades and hues which may be produced by their admixture. Color involves a definite effect produced by the action of light upon the retina of the eye dependent upon the optical composition of the light. This term is also used in reference to material substances such as pigments, stains, dyes, etc., but in specifications it should be recognized that color is primarily a physiological sensation.

Tint.—A color produced by the admixture of a coloring material, not white, with a white pigment or paint, the white predominating.

Shade.—A term descriptive of that difference between colors which results from a difference in luminosity only, the other color constants being essentially equal. A darker shade of a color is one that has a lower luminosity. Primarily the term "shade" is akin to shadow, designating darkness or reduced illumination, and therefore when strictly used should express only such change as depends on reduced luminosity; it has been defined by several authorities as the mixture of black with a color, thus establishing its opposite character to "tint," but by extension of its relative sense it has been frequently and widely used to include lighter shades by use of the adjective "lighter" or "paler." Although such expressions apparently involve a contradiction, it is clear that while we may have a shade of color or darker color of the same sort, it is easy to conceive of another shade not quite so dark and therefore lighter.

Hue.—The predominating spectral color in a color mixture.

Tone.—The color which principally modifies a hue or a white or a black.

Drying.—The solidification of a film.

Drier.—A material containing metallic compounds added to paints and painting materials for the purpose of accelerating drying.

Specific Gravity.—The ratio of the weight of a unit volume of a substance to the weight of an equal volume of water at defined temperatures.

Density.—The use of this term should be avoided if possible. Density is a scientific term meaning the mass of a unit volume. Its numerical expression will vary with the units selected, and there is no occasion for using it when the term "specific gravity" is defined. Confusion may be avoided by not using the word "density" in specifications.

Gallon.—The measured gallon is 231 cu. in. Where a measured gallon is called for, the temperature at which it is to be measured should be specified. Where a gallon of definite weight is called for, the weight should be specified or obtained from the specific gravity of the material at a definite temperature. This is the standard United States gallon.

Water.—Dissolved water or water not definitely or chemically combined.

Dry.—In paint materials; containing no uncombined water. In paint films; completely solidified.

SPECIFIC GRAVITY OF PAINT MATERIALS.

It is often desirable to compute the amount of each of the various ingredients in a paint. The fundamental figures are the specific gravity of the ingredients. It is not at first obvious how to find the specific gravity of a pigment, because it is, when dry, a loose powder, containing in its interstices much air, which is displaced when mixed with oil; but it may be found by using a small flask, which has been accurately measured, and which holds a known volume when filled to a mark; into this is put a weighed portion of pigment, and it is then filled up to the mark with water, alcohol, oil or some other liquid of known weight; various precautions are taken to insure the complete removal of the air. Subtracting the volume of the liquid from that of the flask gives the volume occupied by the known weight of pigment. The following table shows the specific gravity of the more common:

Litharge	9.30
Red lead	8.4 to 8.8
Average of red lead of 98 per cent. Pb_3O_4	8.6
Orange mineral (orange lead)	8.6 to 8.7
White lead	6.6
Basic lead sulphate	6.4
Chrome yellow (medium)	5.8
Zinc oxide (white zinc)	5.55
American vermilion (basic lead chromate)	6.8
English (mercury) vermilion	8.2
Bright red oxide of iron	5.26
Indian red (oxide)	5.26
Venetian red	3.10
Brown oxide of iron (Prince's)	3.2
Ultramarine	2.4
Prussian blue	1.95
Chrome green, blue tone	4.44
Chrome green, yellow tone	4.0
Lithopone	4.25
Ochre	2.94
Sienna	3.26
Umber	3.57
Barytes	4.23 to 4.46
Blanc fixe	4.25
Gypsum (terra alba)	2.3

Asbestine	2.75
China clay (kaolin)	2.6 to 2.7
Whiting (Paris white)	2.65
Silica	2.65
Natural graphite	2.6
Acheson's graphite	2.2
Bone-black	2.68
Lampblack	1.85
Carbon-black (gas-black)	1.85
Willow charcoal	1.49
Keystone filler (slate)	2.66

The chrome yellows vary; orange chrome has more lead in it, which makes it heavier than medium chrome yellow, and lemon chrome has sulphate of lead in it (to make it paler) which also makes it heavier. The density of red lead is variable; in general the higher the percentage of Pb_3O_4 the lower is the density; but this is also influenced by the temperature of making it and the material from which it is made; in general, crystals are heavier than amorphous bodies. The density of litharge varies from 9.25 to 9.52; some of it is crystallized from a fused condition. Orange mineral is red lead made by roasting white lead, and while some of it contains considerable PbO and is correspondingly heavy, some of it has as little as .25 per cent PbO and may have a density of only 8.35.

Linseed-oil is usually considered to weigh 7.76 pounds per measured gallon (231 cu. in.) which corresponds to a density of .931, and turpentine is supposed to weigh 7.1 to 7.2 pounds, or to have a density of about .86. Commercial (petroleum) benzine weighs about 6.2 pounds per gallon, but is variable. A gallon of water at ordinary temperature weighs about 8.33 pounds, and this is the important figure to remember. If we multiply this number, 8.33 by 6.6, which is the density of white lead, we have 55 pounds, which is the amount of dry white lead required to make a gallon; that is, if we thoroughly mix 55 pounds of dry white lead with a gallon of oil, so as to drive all the air out of the interstices of the powder, and replace it with oil, we shall have exactly 2 gallons of a mixture which would be in fluidity intermediate between paste white lead and a paint; but if we mix this 55 pounds of dry white lead with 3 gallons of oil, we shall have 4 gallons of white lead paint. In the same way we may find out the weight of any pigment required to make up the volume of a gallon (when wetted with oil or other vehicle), by multiplying 8.33 pounds by the figures indicating the density of the pigment in question. Thus, the density of lampblack is 1.82 and if we multiply 8.33 pounds by 1.82 we have 15 pounds, which amount of lampblack mixed with 7 gallons of oil makes 8 gallons of black paint; the density of white zinc is 5.55 and multiplying 8.33 by this we have 46 pounds for the weight of a gallon of dry white zinc, which if mixed with 6 gallons of oil makes 7 gallons of white zinc paint.

It will be noticed that to enough pigment to make a gallon we add in the case of white lead 3 gallons of oil, with lampblack 7 gallons, and with white zinc 6 gallons. There is no rule about this; the amount of oil each pigment takes is found out experimentally; but white lead (or perhaps barytes) takes the least and lampblack the most, of all pigments. The volume of oil is, however, much more simply related to the volume of pigments than to their weights. In general, the pigment constitutes from one-fourth to one-sixth or one-seventh the volume of the paint.

A practical problem of this sort arises in a case like this: red lead and oil make a paint much used in painting iron and steel; and commonly the red lead and oil are bought separately and mixed in such proportions as the user desires, according to the character of the work. Thus, 33 pounds pigment to a gallon of oil is used for under-water work; 28 pounds pigment to a gallon for other marine work; 25 pounds or more for bridges, and so on. To find the cost of the paint in each case it is necessary to know not only the cost of materials, but also the volume of paint produced. We find by computation that 72 pounds of red lead make a gallon; then 33 pounds = .46 gallon; 28 pounds = .38 gallon; 25 pounds = .35 gallon and so on, and so these mixtures will amount to 1.46 gallons, 1.39 gallons, 1.35 gallons, and so on. Multiplying the number of pounds of dry pigment by the price per pound, and adding the cost of a gallon of oil gives us the cost of materials of each of these various amounts, from which the gallon prices may be computed; and in no other way can it be done.

Here is another case: Suppose the analysis of a paint shows 80 per cent. white lead and 20 per cent. asbestine, by weight, in the pigment, and that the consistency of the paint is such that it corresponds to a white lead paint mixed up in the proportion of one volume of dry white lead to three volumes of oil, which is common. We know that 92 pounds dry white lead requires 8 pounds oil to make a paste; and we also know that a given volume of asbestine paste contains twice as much oil as the same volume of white lead paste. It takes, we find, 55 pounds dry white lead to make a gallon, and one-quarter of this, 14.25 pounds, mixed with three-fourths of a gallon (=5.81 pounds) of linseed-oil makes a gallon of paint. If 92 pounds white lead take 8 pounds oil for a paste, 14.25 pounds will take 1.24 pounds (=.16 gallon) oil to make a paste and the rest of the 5.81 pounds or 4.55 pounds (=.59 gallon) is used for thinning the paste, the volume of which is .41 gallon. Practically, we are taking one and a half volumes of oil to one volume of paste, and we may assume (though it is not strictly accurate) that this rule will apply to all pastes of similar consistency.

We find by computation that 23 pounds dry asbestine make a gallon; and to find the composition of a gallon of asbestine paint we may proceed as follows: If 92 pounds white lead and 8 pounds oil make a paste, an amount of asbestine corresponding to 84 pounds of white lead requires 16 pounds of oil (=2.1 gallon). 84 pounds white lead = 1.53 gallons and 1.53 gallons asbestine =35.2 pounds, making a total of 3.63 gallons. This is asbestine paste; to make this into paint we add $(3.63 \times 1\frac{1}{2}) = 5.44$ gallons oil, making 9.07 gallons paint, composed of 35.2 pounds asbestine and $2.1 + 5.44 = 7.54$ gallons oil; and 1 gallon contains .83 gallon oil and 3 pounds asbestine. If white lead costs 7 cents and asbestine 1½ cents per pound, and oil 50 cents per gallon (which are usual prices), the white lead paint will cost $1.45 per gallon and the asbestine paint 46 cents per gallon.

Going back to our original analyzed paint, it contains 80 pounds of dry white lead to 20 pounds of asbestine. If 1 gallon of white lead paint contains 14¼ pounds dry white lead, 80 pounds will make 5.61 gallons, and 20 pounds asbestine will make 5.44 gallons or 11.05 gallons altogether; or a gallon contains 51 per cent of white lead paint and 49 per cent of asbestine paint, instead of 80 and 20 as might at first sight be thought, and the cost will be $0.95 per gallon. We are liable to deceive ourselves as to the value of such mixtures unless we bear these principles in mind.

Similar methods may be used for paints containing three or more pigments.

CHAPTER XXIII.

FURNITURE-VARNISHING.

There is an art of varnishing furniture and similar belongings, and also a trade. The latter is divided into many parts, and concerns itself with supplies and methods; the former is a matter of principles and the materials for their embodiment. "Furniture varnish" is a term of reproach among the varnish-makers. It is made of "North Carolina Zanzibar gum," otherwise known as common rosin. If there is a normal price for it, it is about the same as that of spirit of turpentine, but it is often sold for half that sum. The writer has among his archives a letter offering a special brand of it for 9 cents a gallon, in barrels, f.o.b. Cleveland, and soliciting permission to send a barrel sample to a large manufacturer of woodenwares. Nothing was said about discounts, and perhaps this is "rock-bottom." Lest this notice should cause a rush of trade to Cleveland it should be said that cheap varnish is made elsewhere. In fact, if with New York as a centre and a radius infinity we describe a circumference, the furniture varnish-maker will be found to flourish anywhere within the circumscribed area.

In justice to the furniture-makers (though justice is about the last thing wanted, or received either, by the users of so-called furniture varnish), it must be said that a large part of the cheap stuff sold under the name is used, not by the furniture men, but by painters of cheap houses for varnishing interior trim, and by makers of cheap mixed paints. It appeals to the latter as being cheaper than linseed-oil. As a house varnish, the name has been displaced largely of late years by that of "hard oil-finish," but the material remains the same, though of course some makers sell a pretty fair varnish under the latter name, just as some belated individuals or firms make furniture varnish out of varnish-resins and linseed-oil; but they don't sell much of it.

Legitimate Use for Cheap Varnish.—There are two sides, and usually more than two, to most questions; and the man who makes kitchen chairs says that all the varnish is for is to keep the chair looking fresh until it is sold, and that the best varnish will be scrubbed off the chair as quickly as soap and sand will do it after it reaches the kitchen; all of which is true, and as these chairs are turned out at the rate of a car-load a day in some factories the economy in buying cheap varnish, which is purchased in car-load lots, is a substantial one. The varnish serves some such a use as the practice of leaving the edges of books uncut. It is a guarantee that the goods are not second-hand. The varnishing of kitchen chairs, by the way, is done by a method which is a refinement of simplicity and economy. Many years ago the makers of agricultural machinery found that they could paint and varnish their apparatus by dipping it in a tank of paint or varnish, properly thinned; but the chair-makers keep a pump in operation, and a stream of varnish falls constantly into a shallow pan, or drained platform, on the floor. The workman holds the chair in this falling stream, turns it about skilfully, then throws it aside, all varnished except the under side of the chair seat, which does not need it. If the chair were dipped this place also would absorb varnish, which would be a waste, and extravagance is a sin; besides, economies like this make dividends, and keep the company out of the hands of a receiver. So it is with many other things: there is no use in using a varnish which will outlast the piece of furniture on which it is put; and the law of the survival of the fittest does not apply to such things as chairs.

Furniture which does not receive a high polish ought to have as elastic a coating as floor varnish, that is, one containing 12 or 15 gals. of oil to 100 lbs. of resin. Dark woods, such as dark oak and especially cherry and mahogany, should receive a dark-colored varnish, which is made from dark resin. These are cheaper than pale resins of the same kind and are harder and better. Such a varnish may therefore be of excellent quality and moderate price. Many things will stand a still more elastic varnish, a 20-gallon for instance, such as would be put on interior woodwork. This becomes hard enough to rub in a week or two, and if a rubbed but not polished finish is wanted it is hard enough. It would be too slow for factory work, but it would outlast most furniture.

Dark Varnishes.—The reason why dark varnishes are best on dark woods is that their color enhances the beauty of the wood. It is a dark brownish red, and is transparent. The effect of a transparent color is far more brilliant than that of an opaque one, and three or four coats of such a varnish are like a layer of colored glass: it seems as though one could look down into the wood. The more varnish is applied the more pronounced is this effect.

Brilliance.—The larger the proportion of resin the more brilliant is the varnish, and the richer in depth of color. This is probably one reason why varnishes approaching the type of carriage rubbing-varnish are so much liked on furniture, in spite of their diminished durability. The brilliancy of a varnish, like that of a gem, depends on its index of refraction of light, and this sensibly increases with the increase in the percentage of resin. Therefore in order to get the finest possible effect, on a piano-case for instance, it is necessary to sacrifice durability to an appreciable extent. It it not exactly true that brilliance varies with percentage of resin, for some resins are more capable of imparting this effect than others. An 8-gallon Manila varnish is less brilliant than an 8-gallon Zanzibar. It is a remarkable fact that the index of refraction of a varnish is higher than that of its component parts. It may thence be inferred that this quality is developed in making the varnish, and that skill in the operations will enable one to make a brilliant varnish with a larger proportion of oil than could be used if the operator had less skill; and this is true. A brilliant varnish ought then to be made from the materials which experience has shown to be best, and by a skilful maker, according to a tried and satisfactory as well as a rational formula. There are so many variables that no two varnishes from different sources are likely to be alike; and it is possible for a maker to produce a varnish which is actually better for a special use than any one else has made. This again is practically true; but the art of varnish-making is far from stationary, and the best varnish to-day may be superseded next year.

Filling.—It has been said that the finishing of furniture is much like that of carriages. Of course unpainted furniture, which comprises the greater part of it, receives only priming, filling, and varnish, and the wood-filler used is never lead, but a transparent filler such as silica. The so-called liquid wood-fillers are also used largely on cheap furniture, but nothing good can be said of them. The priming is like all priming, done with linseed-oil; then the wood may be filled with varnish directly. Usually when this is done a rubbing-varnish is used; or a silica filler, such as is used on interior varnished woodwork in houses, may be used. This fills the pores of the wood. Often a colored pigment is mixed with it, the object being to change the color of the wood by filling the pores with color. Sometimes the color of the whole of the wood is changed, as when birch is stained to resemble mahogany. This is done with an oil-and-pigment stain, mixed in turpentine, and applied before the priming; more rarely the wood is treated with a dye. There are a great many dyes which are soluble in alcohol, and some which dissolve in turpentine. These are better than water dyes, as they do not disturb the grain of the wood. Dyeing is necessarily done before anything else.

Varnishing.—When the surface is properly filled it is sandpapered, and is then ready for the varnish. Any good rubbing-varnish will answer, but usually a special rubbing for furniture is employed. The various coats are applied and treated substantially as on carriage-work. The finishing-coat is not usually much different from the preceding ones, because a very elastic varnish is not hard and firm enough for the kind of use furniture receives. It is flowed on with a full, soft brush, and is either left with the gloss, is rubbed to a dull surface, or is polished with rottenstone, as has been described in the chapter on house-painting.

Polishing.—It is a rather common practice for the workman,

VARNISHING ROOM IN A PIANO FACTORY.

By the courtesy of the W. W. Kimball Co., Chicago.

after he has polished the surface as well as he can with rottenstone or some such powder, to finish by rubbing with the palm of the hand. The reader may notice how the well-varnished handrails in business offices get polished by continual handling. This is the sort of finish obtained by hand-polishing, and is the highest possible finish; also the most expensive, for it is an almost inconceivably laborious and tedious task. A good workman will sometimes spend a day on a surface a foot square. It may be worth while to give here a translation from "The Art of the Painter, Gilder and Varnisher," by Watin, published in 1772. This is regarded as the oldest systematic treatise of any value on the subject. Watin's description of the method of polishing is as follows:

"To polish varnish is to give it a surface glossy, clear, and smooth, which can never be secured by repeated coats unless we efface the little inequalities which occur. To do this we use pumice and tripoli. Pumice is a stone which has become light and porous because it has been calcined by subterranean fires, and thrown by eruptions into the sea, where it is found floating. Without regarding its form, there are many sorts, various weights, some gray, some white. Those most esteemed are the coarsest, the lightest, and the purest. It ought to be porous, spongy, with a salt taste. It is brought from Sicily, opposite Mt. Vesuvius, from which it is thrown out.

"When we wish to use it in powder, it is necessary that this powder should be impalpable, so that it will not scratch the work we are polishing.

"Tripoli is a light stone, pale in color, inclining slightly to red, which is brought from many localities in Bretagne, Auvergne, and Italy. It is thought from the lightness of this stone that it has been calcined by subterranean fires. We find two sorts in France. The first and the best is that which is brought from a mountain near Rennes in Bretagne. They find it in beds about a foot thick. It is used by painters, lapidaries, goldsmiths, and coppersmiths to brighten and polish their work. The second, and less valued, comes from Auvergne, near Riom. It will not serve for our uses, but it is used in houses to clean and brighten the kitchen utensils.

"To polish an oleo-resinous varnish, when the last coat is thoroughly dry, proceed as follows: Pulverize, grind, and sift some pumice, so that you may suspend it in water, and with this saturate a piece of serge and polish lightly and uniformly, not more in one place than another, so as to avoid spoiling the foundation. Then rub with a bit of clean cloth moistened with olive-oil and with tripoli in very fine powder. Many workmen use for this pieces of hats; but this always tarnishes the work and may injure the foundation. Wipe it off with a soft cloth in such a way that it shall be bright and show no streaks. When it is dry, polish it with starch-powder or whiting by rubbing with the palm of the hand, and wiping it off with a linen cloth. This last is the operation of polishing. Spirit-of-wine varnishes may, when they are very dry, be polished in the same way, only omitting the use of pumice."

"Vernis-Martin."—Watin, as has been said, was the first writer on the subject. He was an artist and a man of science; but long before his book was written, Robert Martin had established a great reputation, which has lasted until the present time, as a maker and especially as a varnisher of fine furniture. There were three brothers of the name, one of whom, William, established himself as a varnisher at Rochefort, but Robert, whom Watin calls "the famous Martin," was at Paris. Watin speaks of "my profound veneration for all who carry the name of Martin, our masters in the art of varnish," and describes the varnish made by melting copal, adding linseed-oil and turpentine, and says: "It is thus that the famous Martin made his beautiful pale oleo-resinous varnishes, which gave him so much reputation." It is worthy of remark that these brothers were carriage-builders, and that their skill as finishers, at a time when every shop made its own varnish, led them into the more lucrative business of fine furniture, in which they became unrivalled. The later editions of Chambers's Encyclopædia were published at the time when Martin was producing his work. From this source we learn that Martin used an oleo-resinous varnish, a mixture of one-third amber and two-thirds copal, with enough linseed-oil to make, in our nomenclature, about a 13-gallon varnish. Diderot and D'Alembert, in their Encyclopædia, written in Paris about the same time, give the same, only with a larger proportion of oil. Martin's process is thus described by Chambers:

"The article to be varnished, after having been varnished smoothly, and dried in the intervals, half a dozen times, and suffered to dry thoroughly, must be rubbed with a wet, coarse rag, dipped in pumice-stone powdered and sifted, till the streaks of the brush and all blemishes are removed. When it is perfectly smoothed, washed, and dried, the coats of varnish are to be repeated, for ten or twelve times, till there be a sufficient body. After having again used the pumice-stone, and washed it off as before, let it be rubbed with fine emery till the surface becomes even and smooth as glass; then with powder of fine rottenstone, till by passing the palm of the hand two or three times over the same place, you discover a gloss equal to that of glass; having dried it clean, dip a rag, or a piece of flannel, in sweet-oil, and rub the surface a few times over, and clear it off with fine dry powder, flour, or the hand; and a piece of fine flannel, dipped in flour, and rubbed over it, when cleared of oil, will give it an excellent lustre. Between every coat of varnish it will be advisable, if the subject admits of it, to set it in a warm oven, or to heat the varnished pieces by stoves."

Durability of Good Work.—That was the way they finished furniture in the year 1750; that is the finish called "vernis-Martin"; and that finish is on that same furniture to-day. Do not say that varnish is necessarily a short-lived commodity. Remember what Xenophon said about the horse's feet, and the counsel of the prophet Isaiah.

Ancient Practice.—But Martin was not the originator of the method of polishing which he practised. It is mentioned by the monk Theophilus in the tenth or eleventh century, who says that varnish is polished with the hand. Going further back we find that Vitruvius, in the first century B.C., says that wainscotting is varnished, then rubbed and polished. "Subigendi et poliendi," are his words (book VII, chap. 4), and he also says that this rubbing was done with a powder like ochre interposed. Elsewhere the same author uses, with the same meaning, the words "subactum et bene fricatum." Cicero says that Apelles polished his paintings, but possibly this only refers to his skill in varnishing them, of which mention has already been made; but Nicias, who was a painter of the fourth century B.C., is expressly said by Pliny to have "put his hand to" his work, and to have taken "much care in rubbing" it (book XXXV, chap. 28). Thus we have what seems to be a clear case of handing down a technical method for twenty-three hundred years.

Refinishing Old Furniture.—To refinish old furniture it is desirable to remove first the old varnish, not because old varnish is harmful as such, but because we know nothing about it, and if we are to spend a large amount of work on an article we should be sure about the foundation. The old varnish may be removed by scraping it with steel scrapers or with broken glass, then scouring it with sandpaper; or else we may begin with a paint-remover and carefully take off all the varnish, and immediately wash it off with benzine. This part of the work should be done out of doors, for fear of fire. Then apply a thin varnish. This may be from a 15- to a 20-gallon varnish (gallons of linseed-oil per hundred pounds of resin), and should be of good, hard resins, part Kauri and part some hard African resin. This should be thinned with turpentine. Starting with a varnish of ordinary body it is well to add from an eighth to a fifth its volume of turpentine, and this mixture, after being well shaken, should stand in a warm room at least two or three months. This may be regarded as essential, for if used at once, although the original varnish may (and must) have been well aged, the mixture will behave in some ways like a fresh varnish. This thin varnish is carefully brushed on in thin coats, plenty of time being given for each to dry and become hard, at least two weeks between coats, unless there is a hot room, with a temperature of at least 130° F., in which it may be set; then the time will be reduced according to the temperature. Each coat when perfectly dry should be rubbed, at first with very fine sandpaper, but after enough coats have been put on to be sure that none of the water used can reach the wood, powdered pumice and water may be used sparingly. The surface should then be washed with clean water, using a clean brush to get it into corners and depressions, and made perfectly dry and warm before the following coat of varnish is applied. Of course all the precautions against dirt, dust, and dampness which can be thought of must be used, and in particular the brushes must be treated with care. Only as much varnish as is to be used at one time should be taken from the can, which should be then immediately stoppered. Any varnish which has been taken out should not be put back, for fear of getting dirt in the can, a thing which would almost certainly happen. The very thin coats secured in this way will make a body of varnish which is much more uniform and homogeneous than if thicker varnish were used; and the reader will easily understand that these are to be repeated until a thickness has been secured great enough to be rubbed to an even, level surface. Then repeat the treatment until enough varnish has been applied to get the desired lustre; after which it should be rubbed and polished. Always remember the intermediate light rubbing between coats, to get a proper adhesion of the successive layers. Flow on the varnish lightly, but smoothly and rapidly, with a fine new brush, and do not brush it too much or it will be full of bubbles, and if you brush it after it has begun to set it will roll up; then all that can be done is to get it off as quickly as possible with a brush wet with spirit of turpentine, and immediately revarnish; but this should never occur. The successful varnisher works rapidly, with a steady hand, and is not afraid of the varnish; but he does not use too much. The amateur will do well to go from time to time and watch some good workman. The art, like all arts, is learned from observation and practice combined. The amateur should practise by preparing and finishing experimental panels. For this purpose he can buy, in the city shops, cake-boards of a convenient size, dry and smooth, for a trifling sum; nothing can be better for practice.

Violin Varnish.—Occasionally a mechanic, especially an amateur mechanic, is also an amateur musician; a trouble-breeding combination, which sometimes leads to the construction of violins. There is a belief, so universal that it is probably true, as it is inherently reasonable, among violinists that the varnish on a violin affects its musical quality. It is therefore desirable to use a suitable varnish. Books of recipes usually advise using a spirit varnish, which may be colored to suit; but the writer does not believe such varnishes were ever used by the great violin-makers. From the nature of the case it is difficult to get samples for examination, but one can occasionally have an opportunity to look carefully at an old violin, and these always appear to have been coated with an oleo-resinous varnish. A varnish expert has shown me an old violin, about two hundred years old, very valuable, which had in one place what appeared to be the original varnish in a layer of considerable thickness; on this surface a long-continued pressure with the finger-nails made a sensible depression, which afterward disappeared. If this varnish was old, and it certainly was, it must have been made with at least 35 gals. of oil to 100 lbs. of resin; and such a varnish would probably last two or three hundred years, possibly several times that, under the conditions in which a valuable violin is kept. Such a varnish could have had little, probably not any, drier in it. The violin was varnished, put in a dry dust-proof cupboard, and left for some months before the next coat was applied. The time was of no consequence, since it is generally believed that a violin must be kept a year or two after it is made before it is ready for use, and such a varnish would by its perfect elasticity not interfere with the normal vibrations of the wood; whereas the writer is told by experts that spirit varnishes, which produce simply a layer of dry resin on and in the surface, make the tone of the instrument harsh. As to color, in the first place the old instrument-makers made amber varnish. We are accustomed to think of amber as a pale golden-yellow resin, but the sorts used in varnish-making are dark brownish red, and in melting all resins darken very much; so that amber varnish is very dark in color, so much so that it is unsalable for any ordinary work. It might have had color enough to suit the makers; and it is a beautiful, rich, deep color. Then comes in the matter of age. No one can look at one of these old instruments without feeling that the tone of the color is due to age; the long-continued darkening action of light can never be imitated by a dye. There is besides evidence of a historical sort. The great violin-makers lived at the time when the great masters of painting were executing their works in amber and copal varnish, and must have known of the value of these preparations. Eastlake describes a manuscript in the British Museum, dated 1620, written by De Mayerne, who was chief physician to the King of England, and who is well known to have been a man of great and varied technical learning. De Mayerne describes the making of varnish from amber and linseed-oil, as it was experimentally taught him by M. Laniere, who learned it from the daughter of the eminent Florentine painter Gentileschi, whose paints were made with this varnish as the vehicle. This was called the amber varnish of Venice. It was at first turbid but could be settled by mixing brick-dust with it; and De Mayerne says it was commonly used for lutes and other musical instruments. Mrs. Merrifield and others have also collected evidence showing that although turpentine varnishes were unquestionably in common use, yet all the makers of high-priced wares used also varnish made of amber and oil. There is considerable of this sort of evidence, and when taken in connection with the fact, which probably most experts would agree upon, that the varnish on these old instruments appears to be oleo-resinous, and the further unquestioned fact that no spirit varnish of such qualities is known to us either experimentally or by tradition, it seems that we are warranted in believing that such varnishes as have been described were the ones used by the more important makers of violins; and that we are to advise the use of a carriage finishing-varnish unless one darker and more elastic can be had. Probably most varnish-makers can supply a 25- to 30-gallon dark varnish, although they do not ordinarily sell it unmixed with a harder one. If the writer were to make a special varnish for this use it would be a straight amber varnish, with 35 or 40 gals. of raw linseed-oil.

To revert for a moment to the subject of furniture, it should be said that the makers of the better class of these goods use very good varnish, not unfrequently thinned with benzine instead of turpentine, for cheapness, which accounts for brush-marks often seen on articles which are left with the natural gloss, and the finish is surprisingly good when we consider the price received for the finished furniture. Such a finish cannot be produced if a very poor varnish is used.

Brushes.—A few words may be here added concerning the proper care of varnish- and paint-brushes. If these are left to dry with the varnish or paint in them they are spoiled; they are to be cleaned thoroughly, or else kept in some liquid which will preserve them. As to what this liquid should be there is difference of opinion; some put the brushes in water, some in linseed-oil, some in varnish, but probably the most use turpentine. Whatever liquid is used the treatment is the same; the brush is not immersed, handle and all, but is suspended in a vertical position, dipping just far enough in the liquid so that it comes up to where the bristles (or hair) disappear in the binding which unites them to the handle. The brush should not rest on the point of the bristles, as this will injure its shape and, in time, its elasticity, but should be hung up by the handle. Tin boxes for this purpose, called brush safes or keepers, are for sale by the dealers. They are tightly covered to prevent evaporation and to keep out dust, and have hooks or other attachments for suspending the brushes. A simple and perfectly good keeper for one or perhaps two brushes may be made by soldering to a tin cup (one without a handle), or a small empty can with the top removed, a wire; this wire stands vertically when the cup is on its bottom, and reaches up about as high as the length of the brush, handle and all. Then bend this wire at right angles, say 2 ins. below the top, so that the bent part may overhang the cup. Make a good-sized hole in the handle of the brush at a suitable place, so that when it is hung on the bent part of the wire it will hang in the cup, the bristles just clearing the bottom. Then fill the cup with turpentine or oil, so as to wet the bristles; and to keep out dust the whole thing may be lowered into a glass fruit-jar and the top screwed down. In order to more easily lower the apparatus into and draw it out of the jar, it is common to solder a second piece of wire to the first, projecting above it, for a handle. This is a cheap and satisfactory arrangement and illustrates the principles on which all brush safes should be constructed. Brushes used in spirit varnishes should not be put in water, but in alcohol, and if a brush is to be put away for a long time it may be washed out with turpentine or benzine (a spirit-varnish brush in alcohol, usually wood-alcohol), and when as clean as it can be conveniently made in this way it may be washed out with soap and water, very thoroughly rinsed with clean water, and dried as quickly as possible. Each brush should be separately wrapped in clean paper, and kept in a dry place.

As to choice of brushes, that is too large a subject to be treated here. The student will do well to write to some of the brush-makers for an illustrated catalogue, and by studying that, get some idea of the sorts and shapes of brushes in use, after which he may ask advice of the professional painter who is doing the sort of work which interests the amateur. There is considerable room for the personal equation; but all agree that good work cannot be done without good brushes, and the best brushes quickly cease to be good if not kept clean.

CHAPTER XXIV.

CONCLUSION.

It is probable that many of the readers of this book will feel a reasonable interest in knowing something about the former practice of those who made and used the products which have been described. Many references of this sort have been incidentally made. Our knowledge of former applications of the art is not continuous, nor even connected, but the total amount is considerable; more concerning its decorative and artistic branches than of the technical side. Pliny's Natural History is the great fountain of knowledge of such things; much may be learned from Vitruvius and Dioscorides. These writers had access to writings and other sources of information now lost, and no doubt they give reasonably correct accounts of earlier practice, and there is no reason to doubt their accuracy when they describe their own times. Aside from these writers we may only pick up occasional bits from the more ancient writers, introduced incidentally, and to illustrate some other matter. Thus, in Xenophon's "Economist" one of the speakers tells that his wife was at one time in the habit of rubbing white lead into her skin to make her face look white, and then dyeing her cheeks and lips with alkanet to make them red, and adds that she also wore high-heeled shoes to make herself tall; which shows that white lead has been properly valued for twenty-three centuries at least. It is pleasing to be able to add that in this particular case the husband assured his wife that he would love her just the same if she washed her face and put on comfortable foot-gear; and she, being recently married, and knowing that she was young and pretty anyway, did as he advised, and of course had continued to do so up to the time when he told of it. It is unnecessary to say that the use of white lead as a cosmetic did not cease; and we find in Cennini's time that not only was paint used, but that one of the branches of the artist-painter's work was to paint, and not only to paint but to varnish, people's faces. Hear him:

"Sometimes, in the course of your practice, you will be obliged to paint flesh, especially the faces of men and women. You may temper your colors with yolk of egg; or, if you desire to make them more brilliant, with oil, or with liquid varnish, which is the most powerful of temperas. But should you wish to remove the colors or tempera from the face, take the yolk of an egg, and rub a little of it at a time on the face with the hand. Then take clean water that has been boiled on bran, and wash the part with it; then take more of the yolk of egg, and rub it again on the face, and again wash it with the warm water. Do this many times until the color be removed from the face." (Chap. 161.)

In another chapter he expresses his disapprobation of the practice, saying:

"It sometimes happens that young ladies, especially those of Florence, endeavor to heighten their beauty by the application of colors and medicated waters to their skin. But I advise you, that if you desire to preserve your complexion for a long period, to wash yourselves with water from fountains, rivers, or wells; and I warn you, that if you use cosmetics, your face will soon become withered, your teeth black, and you will become old before the natural course of time, and be the ugliest object possible."

Between Cennini, who described the art as practised in the fourteenth century, and the classical writers there are many authorities of more or less importance. The best known is the monk Theophilus, a varnish formula from whom has already been given; but there are others, both earlier and later. Theophilus is especially eminent for two reasons: his work is a systematic treatise on various arts, giving simple and intelligible working directions; and there exist several manuscript copies, showing that it was widely known. This is also evident by the extracts from it found in later writers. Among the earlier writers is Eraclius, who is by some authorities assigned to the seventh century. He was at any rate prior to Theophilus, as has elsewhere been mentioned; his style indicates an early date. The formula he gives for refining linseed-oil has already been given. It is noteworthy that he says this refined oil was used for mixing with pigments, showing that oil painting was practised in his time. The carriage-painter will be interested to read how Eraclius recommends preparing the surface of wood, particularly his way of making rough-stuff:

"First plane the wood perfectly, rubbing the surface at last with shave-grass. If the wood is of such a nature that its roughness cannot be reduced, grind dry white lead on a slab, but do not grind it so finely as if you were to paint with it. Then melt some wax on the fire; add finely pulverized tile and the lead already ground; mix together, stirring with a small stick, and suffer the composition to cool. Afterwards, with a hot iron, melt it into the cavities until they are even, and then with a knife scrape away inequalities; and should you be in doubt whether it is advisable to mix white lead with wax, know that the more you mix the harder it will be. The surface being smooth, take more white, finely ground with oil, and spread it thinly, with a brush adapted for the purposes, wherever you wish to paint; then let it dry in the sun. When dry add another coat of color as before, rather stiffer, but not so stiff as to make it necessary to load the surface, only let it be less oily than before, for great care is to be taken never to let the second coat be more fat than the first. If it were so, and at the same time more abundant, the surface would become wrinkled in drying."

This is a remarkable passage, when we consider that it was written a thousand, and probably twelve hundred years ago. The remark that lead to be used as a filler should not be too fine is evidence of great discernment; and the use of powdered tile for the necessary grit in the rough-stuff is excellent. Wax was used instead of varnish; probably wax may make a good vehicle, but more difficult to apply than the other. It was mixed with a stick; this was a common precaution to avoid getting a trace of iron into the compound. Compare Cennini's use of a wooden spatula for scraping the porphyry slab on which colors are ground. Then note that the surface was levelled and cleaned with a knife, exactly as "knifing-lead" is used on wagon-bodies to-day. Shave-grass is the scouring-rush, a species of Equisetum, and was used as we now use sandpaper, down to quite recent times. It is full of spiculæ of silex and is a perfectly good substitute for sandpaper, only less rapid in its action. Evidently the man who wrote this account was skilled in the art, and the art itself was not of a crude sort. Cennini, who wrote six hundred years later, gives directions essentially similar. His details are scattered through the book and are not readily copied as a whole. He recommends the use of bone-dust as an ingredient of a filler. He says:

"For this purpose take the bones of the ribs and wings of fowls or capons, and the older they are the better. When you find them under the table, put them into the fire, and when you see that they are become whiter than ashes take them out and grind them well on a porphyry slab, and keep the powder for use." The translator remarks that this rather singular allusion to the manner of the times shows that the practice of picking bones, and throwing them under the table, was universal. Eastlake says that as late as the middle of the nineteenth century Spanish painters saved chicken-bones from the table for a similar purpose. Cennini says that some boards which are to be painted are "primed with chalk mixed with white lead and oil, using the bone-dust as before mentioned." Parchment was also filled in this way. He also describes a filler made of gypsum; but what is more interesting, he describes the use of a guide-coat, by sifting powdered charcoal over the surface of the filler, laying it smoothly with a feather; when the rubbing is afterward completed it will be seen that this guide-coat has disappeared. He says of the surface of the wood: "Let it be made quite smooth; if it be defaced with knots, or if it be greasy, you must cut it away as far as the grease extends, for there is no other remedy. The wood must be very dry; and if it be such a piece that you can boil in a cauldron of clean water, after the boiling it will never split. Let us now return to the knots, or any other defect in the smoothness of the panel. Take some glue, and about a glassful of clean water, melt and boil two pieces in a pipkin free from grease; then put in a porringer some sawdust, and knead it into the glue; fill up the defects or knots with a wooden spatula, and let them remain. Then scrape them, with the point of a knife, till they are level with the rest of the panel. Examine if there be any nail, or other thing, that renders the panel uneven, and knock it into the panel; then provide some pieces of tin-plate, like small coins, and cover the iron with them. And this is done that the rust of the iron may not rise through the ground. The surface of the panel cannot be too smooth." (Chap. 113.) Note the use of the wooden spatula, to avoid marring the wood, as we now use one in puttying interior woodwork.

The same writer gives directions for boiling oil, but none for making varnish; but his description of varnishing pictures appears to be the earliest complete account of the operation, and for that reason deserves reproduction: "You must know that the longer you delay varnishing your picture after it is painted, the better it will be. And I speak truth when I say, that if you would delay for several years, or at least for one year, your work will remain much fresher. The reason for this is, that the coloring naturally acquires the same condition as the gold, which shuns a mixture with other metals; so the colors when mixed with their proper tempera dislike the addition of other mixtures to their own tempera. Varnish is a strong liquor, which brings out the color, will have everything subservient to it, and destroys every other tempera. And suddenly, as you spread it over the picture, the colors lose their natural strength, and are powerfully acted on by the varnish, and their own tempera has no longer any effect on them. It is therefore proper to delay varnishing as long as you can; for if you varnish after the tempera has had the proper effect on the colors, they will afterwards become more fresh and beautiful, and the greens will never change. Then take liquid and clear varnish, the clearest you can obtain; place your picture in the sun, wipe it as clean as you can from dust and dirt of every kind. And varnish it when there is no wind, because the dust is subtle and penetrating; and every time that the wind blows over your picture you will have more difficulty in making it clean. It will be best to varnish it in a green meadow by the sea-side, that the dust may not injure it. When you have warmed the picture and the varnish also in the sun, place the picture level and with your hands spread the varnish well over the surface. But be careful not to touch the gold with it, for varnish and other liquors injure it. If you do not choose to spread the varnish with your hand, dip a piece of clean sponge into the varnish and spread it over the picture in the usual manner. If you wish the varnish to dry without sun, boil it well first and the picture will be much better for not being too much exposed to the sun." (Chap. 155.)

It may be well to repeat that the word tempera means the liquid, or vehicle, with which the colors are mixed; modern painters often use it as though it meant only a vehicle for water-colors, but there is no doubt that the word was commonly used exactly as we use the word vehicle. In chapter 161, already quoted, Cennini says: "You may temper your colors with yolk of egg; or if you desire to make them more brilliant, with oil, or with liquid varnish, which is the most powerful of temperas."

It is evident that in his time it was well known that paint required age, at least a year, to reach a condition of permanence. He devotes several chapters to the subject of painting with linseed-oil; he also describes gold size (doratura), which was made of linseed-oil, boiled on the fire, in which was ground some white lead and verdigris; to this was added some varnish resin, and the whole was boiled all together for a short time. This was applied, as thin a coat as possible, and left until the next day, when it was tried with the finger, and if tacky it was ready for the application of the gold-leaf. He adds that this is made for immediate use; if it is to be kept in stock the verdigris is to be omitted.

The whole of Cennini's treatise, which was translated into

English by Mrs. Merrifield (who also translated several other Italian treatises on art of much interest) in 1844, is worthy of careful study; the more so since he wrote at the time when the art of painting was about to receive its greatest advancement. It is said that the method of painting with oil as vehicle was discovered by Jan Van Eyck, a Flemish painter, otherwise called John of Bruges, in 1410. Cennini's treatise was written several years after this date, but he was at the time of its writing an old man, and he expressly says that his methods are those of the middle of the preceding century. It is clear that oil as a vehicle was not first used by Van Eyck; it was known to Eraclius, to Theophilus, and as has been seen in an earlier chapter, was used in England in the thirteenth century. Cennini says it was in common use in Germany; and it is probable that it was known throughout the whole, or nearly the whole, of the Christian era. Van Eyck no doubt invented something; but it was some improvement in materials and processes, not something radically new. All the experts agree that his paintings, and those of his pupils, are made with an oleo-resinous varnish as a vehicle; but he did not invent the varnish, nor was he the first to use it as a vehicle, for Cennini says that varnish is the most powerful of all vehicles. It is possible that he first saw the advantage to be gained by thinning varnish with turpentine; none of the recipes prior to his time speak of this, and it seems to have been the common practice to rub the varnish on with the finger, which would be correct if it were not thinned; it is expressly stated that it will be too thick if laid on with a brush. To adapt it to artistic painting it must have been thinned; the paintings made with it by the great masters show brushwork of the most skilful and delicate sort.

In illustration of this it will be interesting to quote one or two authorities. Gulick and Timbs, whose book was published in 1859, say:

"Probably every person who sees for the first time a picture by Van Eyck, if not surprised by its antiquated treatment or quaintness of expression, will be very much astonished to find that the work of the reputed inventor of oil-painting has preserved its brilliancy of tone after the lapse of more than four centuries far better than most pictures executed within the last hundred or even the last fifty years. By 'brilliancy of tone' we do not mean the force and depth, the luscious richness of color and fulness of effect which are the principal charms of painting in oil, as exhibited particularly by the Venetian school; but that the color of Van Eyck, though quiet, will still be vigorous and fresh; that it will have limpid transparency, and an almost illusive vacuity of space. In addition to this, it will exhibit an amount of truthful realization of the most minute and exquisitely delicate details which is scarcely ever found united with the same imperishable durability elsewhere.

"These characteristics distinguish more or less all the early Flemish pictures; and from persons habitually engaged in restoring them we learn that the colors of these pictures are mostly of a harder body than those of a later date; they resist solvents much better; and if rubbed with a file, they show a shining appearance, resembling a picture painted in varnish. Examination of the pictures themselves, and the researches of several learned writers within the last few years, leave us no room to doubt that their durability is attributable chiefly to the vehicle employed, and that the colors were used not simply with oils, but with an oil-varnish of the kind we call 'hard,' or in other words, an oleo-resinous vehicle, such as might strictly be employed as a varnish over a picture when finished."

The same authors say in another place that "it is probable that varnishes composed of resins dissolved in oil have been used in the most ancient times. Beyond all doubt the composition of varnish was known in Persia, India, and China before the best period of painting in Greece; and it is, then, not to be supposed that the Greeks were unacquainted with this art."

Another well-known English critic, Sarsfield Taylor, who wrote in the first half of the last century, says:

"That he [Van Eyck] had, whether he did or did not invent it, a very superior vehicle for painting is unquestionable; and his pictures, after having been above four centuries painted, are almost in as bright and firm a state as when they first came off the easel. It is feared that his secret has long been lost, and that it was not the ordinary mixture of oils and colors, such probably as was used here [in England] at that time, is very evident; for none of our early oil-color pictures can stand any competition with those of John and Herbert Van Eyck for clearness of light and shade, brightness of hues, or state of preservation; it has all the same advantages over works of the French school painted two or three centuries ago."

It may well be noted in connection with the numerous formulæ for making varnish known in times earlier than that of Van Eyck, that Facius, an Italian historian contemporary with that painter, says that Van Eyck was familiar with the writings of the ancients.

Eastlake relates that the English landscape painter, Fairfield, had learned the use of oleo-resinous varnish as a vehicle from the Dutch painter Van Strij, who was a successful imitator of Cuyp, and though not a contemporary of that painter was well acquainted with his methods; and he assured Fairfield that hard copal or amber varnish was Cuyp's ordinary medium. This agrees with the remarkable hardness of Cuyp's paintings; and this seems to be a consecutive tracing back of this vehicle for a period which now amounts, if we reckon to the elder Cuyp, whose processes appear to be the same as those of his more famous son, to nearly or quite three hundred years. Rembrandt is said by his contemporaries to have painted with amber varnish; and Sir Joshua Reynolds, who was always experimenting with vehicles and pigments,—it is said that he destroyed pictures by the older masters to get the materials for analysis,—and was certainly competent to form a correct opinion, said that Rubens used oleo-resinous varnish as a vehicle. Leonardo da Vinci, certainly one of the greatest of Italian painters, is commonly said by connoisseurs to have used varnish as a vehicle; and about 1515 he was commissioned to paint a picture for Pope Leo X. Vasari relates the story in his Lives of the Painters. It seems that

Da Vinci had recently come to Rome. As was common practice among artists he prepared his own materials, and not having yet had time to supply himself, he began first to make them. Leo inquired the cause of the delay and was told that the painter was getting oils and resins to make his own peculiar varnish. This the Pope criticised, thinking that varnish was the last thing needed, as was indeed the case with distemper painting. The painter became angry and left the court.

Various authorities might be quoted to show that the use of oleo-resinous vehicles, which rendered a final varnish needless, was common still in Flanders in the seventeenth century.

As we come down to more recent times it becomes, of course, easier to find more material; but enough has been said to satisfy the reader that the extreme durability of the work of the great masters of painting was connected with their use of amber varnish or its equivalent. If the reader will remember what has also been said in a former chapter of the value of a white background and the use of semi-translucent paints over it, and will then note the readiness with which such paints may be made, even with very opaque pigments, by mixing them with varnish, and the difficulty of doing this with the vehicles in earlier use, even with oil, it will be plain that this vehicle added so greatly to the brilliancy of pictures that a new era was opened; men of artistic taste were irresistibly attracted to this new art, and so arose the great revival and renewal of the painters' art. If it be said that the same reasons exist now and that nevertheless the use of varnish has again given place to oil, the answer is, first, that the early painters had very few colors, and to get intermediate effects painted a thin color over one already laid on, while modern painters have an almost indefinite variety. Sir Humphrey Davy, who gave great attention to this matter, states that "the earlier Grecian masters used only four colors, namely, Attic ochre for yellow, sinopis for red, the earth of Melos for white, and black." Ivory-black is said to have been invented by Apelles. Boschini relates a remark of Titian, that whoever would be a painter should be well acquainted with three colors, and have perfect command over them, namely, white, red, and black. Cennini recommends only twelve pigments, ten of which could be used in oil; he knew no brown pigment, though modern painters have fifteen or twenty of this color. The second answer is, that in fact, so far as we can judge, modern paintings do not equal those of the masters of the middle ages in permanence. As has been before remarked, the unequalled facility with which oil can be used has been the cause why it has displaced varnish. For glazing colors some painters now use a mixture of mastic varnish and boiled linseed-oil, called megilp. This has been used for many years; but it was known and discarded by the artists who lived before Van Eyck. In Vasari's life of Antonello da Messina he informs us that the painter, when seeking for a vehicle, had tried the experiment of mixing liquid varnish with their oil colors, and that the result had been unsatisfactory. The translator of Cennini says: "It is somewhat curious that the painters of the nineteenth century should have revived and practised, as a new invention, what those of the fourteenth century had tried and rejected; and more extraordinary still, that, unwarned by experience, they should continue to use it, in spite of the awful gashes and cracks that disfigure the pictures painted with this vehicle."

The literature of paint and varnish as now technically used really begins in the last part of the eighteenth century; the first notable treatise is that by Watin, published in 1772. This author was familiar with the art of varnish-making, and gives explicit directions for making oleo-resinous varnishes, spirit varnishes, and those made by dissolving resins in the essential oil of turpentine. The book passed through many editions; it contains directions for executing a great variety of work in painting, varnishing, and gilding. A general idea of Watin's knowledge of varnish-making may be had by reading his precepts, or general principles, which he made for the guidance of his readers.

ON THE COMPOSITION OF OLEO-RESINOUS VARNISH.

I.

Copal and amber are the two principal substances used in oleo-resinous varnish; each of these two materials combines solidity and transparence, which are the primary qualities of varnish.

II.

Copal and amber are not used together; copal, being whiter, is reserved for the more transparent varnishes; amber, a harder resin, serves for gold varnish or to make varnish to be used over dark colors.

III.

Amber and copal can be dissolved, as has been already said, in oil, but we believe it is a better plan to melt them alone over a naked fire. By so doing, they are less liable to be scorched and are always whiter and more clear. When we dissolve them in oil they darken, for as they are difficult to dissolve it is necessary to have a very violent fire.

IV.

The oil which is employed either to dissolve or to mix with the melted resin ought to be perfectly clarified and as pale as possible. It is not permitted to use any oil in making varnish which is not siccative, otherwise it would never dry.

V.

To dissolve amber or copal it is necessary to cook them alone and dry; and when they are well melted, which is known by their fluidity, we are to add the proper quantity of prepared fixed oil.

VI.

Never put several ingredients together to dissolve or melt, since the more manageable will be first liquefied and will be scorched before those which offer more resistance will have arrived at the like condition.

VII.

To melt the resins it is proper to have a glazed earthen pot which can be covered with a lid. This must not be full because we are to add to it the oil and spirit of turpentine, and there must be room besides for it to swell up without overflowing.

VIII.

Set the glazed earthen pot containing the resin over a naked fire of glowing charcoal which does not blaze, for fear of setting fire to the contents.

IX.

In fusing the resins avoid heating them too much. They will turn black and lose their valuable qualities; too much scorched they will be of no use.

X.

We recognize that the resin is in the proper state of fluidity to receive the oil when it offers little resistance to the iron stirring-rod and runs off from it drop by drop.

XI.

When we are ready to incorporate the oil with the melted resin, it ought to be very hot, almost boiling, but it ought to be well purified and clarified. It is necessary to heat it only at the moment when it is to be used. If it is used cold it will dissolve less often melted resin, and by cooling will harden it; while if both are of the same temperature they will be rendered more compatible.

XII.

Do not add the prepared oil until the resin is completely fluid, ready to receive it, which will occur only after it has boiled up several times. In adding the oil, turn it in little by little, stirring it always with the spatula. Let the mixture finally be united by boiling it up several times over the fire.

XIII.

When the oil appears cooked with the resin, take away the pot from the fire, and when it has partly cooled and is only warm turn in, with constant stirring, the spirit of turpentine, which ought to be in larger quantity than the oil. If, when the spirit of turpentine is added, the oil is too hot, the spirit will take fire and burn the varnish.

XIV.

Skilful manipulators, when they wish to make a very fine varnish of copal or amber, do not wait until all the resin is melted. When the greater part is boiling and appears to rise up and then settles down, then they add the oil, which combines with the part of the resin which is melted and does not dissolve that which is not yet fused. By this means the copal and amber are not subjected to a too prolonged heat and are, therefore, more clear and more beautiful. If, when the oil is incorporated, the operator tries to dissolve the unmelted resin, then, as I have already said, he darkens the varnish.

XV.

The varnish being made, it is necessary to be careful to strain through a cloth, to remove any foreign matter which may be in it. If any unmelted pieces are found these must not be put back on the fire with the melted resins, as this would result in making the varnish dark in color.

XVI.

You may put the pieces of unmelted gum by themselves into the earthen pot and recommence to liquefy them, afterward adding oil and spirit of turpentine; but you may be sure that the second varnish will not be as white as the first, for the reason that the resin has been impregnated with oil and will turn dark in cooking. If one does not wish to use up immediately these pieces of copal or amber, and if one has the time to let them dry in the sun and separate them from their oil, they may subsequently be used as though they had never been treated.

XVII.

Let the varnish settle at least twice twenty-four hours to clarify it. The longer it stands the more it will clear and it does not clear so quickly as spirit-of-wine varnish.

XVIII.

Oleo-resinous varnish, if properly kept, becomes more beautiful, but grows thicker. It is necessary, when one is ready to use it, to mix with it a little spirit of turpentine and to heat it for a time in a water-bath. This clears it.

XIX.

When we wish to make fine pale oleo-resinous varnish, it is necessary each time to use a new melting-pot, for usually the action of the fire cracks the glaze, and the oil and turpentine enters these cracks and penetrates the earthenware. Then when we again attempt to melt resins, these liquids which have been absorbed ooze out and burn and mix with the resins and blacken them. Those who do not use this precaution will be much surprised to not have the same result as before, and will not know to what to attribute this accident.

XX.

In fine summer weather these varnishes ought to dry in twenty-four hours. In the winter the varnished objects are usually put in ovens or in a room where there is a hot fire. They dry more or less rapidly according to temperature.

XXI.

The oil, as has been observed, is incorporated with the resins only to preserve them in a fluid condition and prevent them from coagulating; but as the oil is thick, the spirit of turpentine renders it more freely flowing, more easy to spread and to dry.

XXII.

It is necessary to use spirit of turpentine, without which the varnish will never dry. The quantity is commonly double that of the oil. We use less turpentine in summer because the oil, drying more quickly by the heat of the sun, becomes thick more rapidly and the work dries from the bottom. On the other hand, in the winter, when the heat is less, and often only artificial heat, we put in less oil so that the varnish may dry more quickly, but we also add more spirit of turpentine, which evaporates more easily.

XXIII.

The less oil there is the harder and quicker drying is the varnish; as the oil is increased it loses its body, but it spreads more easily.

XXIV.

A very large proportion of oil in a varnish hinders its drying, and if there is too little, it cracks. It is not possible to determine the precise quantity. The ordinary proportion is, to incorporate with each pound of copal or amber from a quarter to a half pound of oil.

General Precepts on the Making of Varnish.

I.

All varnish ought to contain material which is durable and brilliant. These two qualities constitute the beautiful and the good in varnish. It ought to be very quick-drying, hence it is necessary that the liquids which are employed to dissolve the materials should be perfectly dehydrated and siccative

II.

All bitumens and resins suitable for making varnish, if they are heated too much, will become burnt when they are brittle and may be reduced to powder, and when we try to polish them, we find they are worthless.

III.

It is necessary to clean, select, and break into little pieces all the resins used in making varnish but not to reduce them to powder before melting, because the powdered resin will stick to the sides of the interior of the vessel and very easily become scorched. It is most easily melted when it is in little pieces.

IV.

It is forbidden by various regulations to make varnish in the middle of towns. This is a prudent policy. The resins are so combustible, they are able to cause serious fires; besides which, their odor is so penetrating that it is noticeable at a distance and is disagreeable to the neighborhood; so that varnish-makers are obliged to work outside the city limits and in the country. They are not so particular in regard to spirit-of-wine varnishes, yet they are not less dangerous. It is important that one's attention should be constantly on the work, and to take every precaution against accident. It is necessary to make all solutions by day and to avoid artificial light. If the operator, working in an obscure place, should wish to bring a wax taper or a lighted candle near the work, the vapor of the resins, the spirit of wine, or the oil may take fire and cause a conflagration. It is necessary, in case of accident, to have several sheepskins or calfskins, or cloths folded in several thicknesses, always kept wet, to throw over the vessels which contain the varnish materials, to smother the flame.

V.

The action of fire serves to combine the liquids and resins which, by their union, make varnish, but it is not possible to determine the time during which the heat must be applied; that depends on the intensity of the fire, which should be kept perfectly steady, neither increasing nor diminishing.

VI.

If the workmen should get burned, in order to prevent blisters, the wound should be at once wet with spirit of wine, or wrapped with a compress wet with spirit of wine, then cover the wound with a plaster of olive-oil and litharge which have been rubbed together until they become a smooth pulp.

VII.

Varnish is sometimes made of various colors. The Dictionnaire Economique gives numerous recipes, but such varnishes are less fine than the others. The substances which are put in to color them change their character and, not dissolving, always form a sediment which dulls the surface. It must, therefore, be remembered that it is much better to apply a suitable color first and afterward put on the varnish, which, if it has been well made, will not at all change the tone of the colors.

VIII.

A general rule, which should never be forgotten, is to always keep perfectly clean and well stoppered the vessels which hold the materials from which the varnish is to be made as well as those in which it is to be kept, for nothing evaporates so easily as a varnish; and a varnish which evaporates becomes thick and darkens and changes the colors over which it is used.

IX.

When the varnish is made, it is carefully purified, as much as is possible, from all dirt and dust, by passing it through a strainer of silk or fine linen, and when it is purified, care should be taken to close the bottle which contains it, for fear that particles of dust may fall into it.

X.

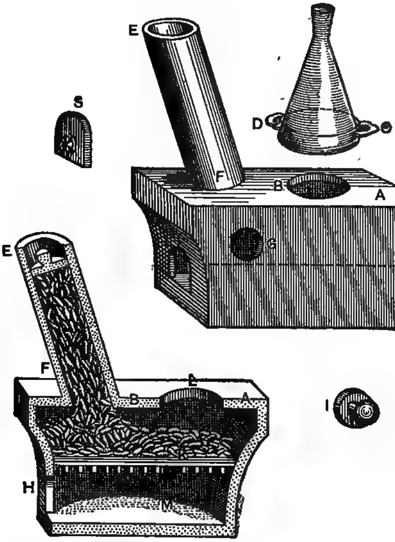
The nature of the object to be varnished should determine the kind of varnish to be used. If it is to be exposed to the weather, it is necessary to use an oleo-resinous varnish. If, on the contrary, it is to be kept within doors, cared for, and preserved in the interior of the house, then we may use spirit-of-wine varnish, which, while it is brilliant, gives off no odor, dries quickly, and is durable as long as it is not too much exposed to the air and the sun. As for varnish of spirit of turpentine, it is, except such as are used on paintings, hardly deserving the name of varnish. Those which are called so are in reality commonly composed of common resins which will dissolve together and of which the turpentine is the foundation.

XI.

Oleo-resinous varnishes endure easily the heat of the sun, because the amber or the copal which they contain are too durable to be changed. Sandarac, on the contrary, which is the base of spirit-of-wine varnish, is affected by the sun and cannot long resist it when made into a varnish. This one often sees in the heat of summer, when the spirit-of-wine varnish on the interior of rooms suffers decomposition and gives off an odor, as if it were not well made.

XII.

Varnish is made in glazed earthen pots which are commonly changed at each operation, for a reason given elsewhere.



This illustration represents a varnish-maker's furnace, date about 1778; from the thirteenth volume of the Oeconomische Encyclopedie. The fuel was charcoal. The resin was melted and the varnish made in the flask.

The next book of importance was the "Painters' and Varnishers' Guide," published in Geneva in 1803, and written by

P. F. Tingry, a chemist and scientific man of some note. He was a member of the Society at Geneva for the Encouragement of the Arts, Agriculture, and Commerce. As this society desired that a methodical description of the art of varnishing should be a part of their publications, and as Tingry had lectured both publicly and privately on the subject, they requested him to undertake the work. His book brought it up to about a third of a century later than the treatise of Watin. It passed through numerous French and at least two English editions. He notices the fact that formulæ for making both varnishes and colors had long been known, and asserts that Watin was the first to systematically weed out the useless and explain the sequence of the valuable ones, thus establishing a method of study which subsequent writers might enlarge and perfect. He gives twenty-nine varnish formulæ. These are divided into five classes, or genera, of which the first includes three kinds, called drying-varnishes made with alcohol. Two contain only mastic, sandarac, and Venice turpentine for solid ingredients; the third contains a small amount of "powdered copal of an amber color," and previously melted. In all cases these are made in batches of about one quart, in glass flasks immersed in hot water, stirred continually with a stick, and cleared by settling with powdered glass. He mentions the use of camphor as an assistant to solution. The second genus includes seven varnishes, also having spirit of wine as the solvent, made in the same quality and manner as those already described, but less drying than the first genus, by which he means less hard and more flexible. The various ingredients are sandarac, elemi, anima, rosin, shellac, Venice turpentine, mastic, benzoin, copal, or amber (not all these resins in any one varnish, but three, four, or five), camphor to assist the solution, and in some of them coloring-matter was added, the list being dragon's-blood, sandalwood extract, saffron, gamboge, and extract of canna indica. In all cases he uses 10 or 12 ounces of resinous matters to a quart of alcohol, or about half as heavy a varnish as our modern standard shellac.

This third genus of varnishes has spirit of turpentine for a solvent. The resins are mastic, which is always used in this class, so is Venice turpentine; sandarac and seed-lac are also used, and coloring-matter as before. These varnishes are for application to finished paints, or for metals and wooden boxes. The batch is about one quart, and is made in the way already described. There are six of these formulæ.

The fourth genus, six in number, is based on copal, by which Tingry meant apparently a soft copal like Manila. At all events, it was wholly soluble in ethylic ether ("sulphuric" ether), and partly soluble in alcohol. One of the solvents in this class is essential oil of lavender. The powerful solvent qualities of this liquid are believed to be due, at least in part, to a camphor which it contains. He also added about 2 per cent. of camphor to the oil of lavender. The principal solvent or diluent was spirit of turpentine. It is worth noting that one of these varnishes was suitable for the varnished wire gauze used in ships instead of glass.

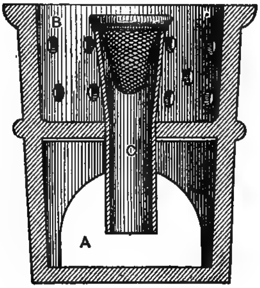
The fifth genus comprises what he calls fat varnishes, or oleo-resinous varnishes. The materials which enter into their composition are copal, amber, prepared linseed-oil, nut- and poppy-oil, and essential oils, especially spirit of turpentine. In all cases the resin was first melted and the oil afterward added to it in the usual manner. Four to eight ounces of resin made a batch. Seven formulæ are given, only five of which are of true oleo-resinous varnishes: one is a gold size, and one is caoutchouc dissolved in oil. His own preference was for varnishes of the fourth genus; but he admitted that for durability oleo-resinous ones must be used.

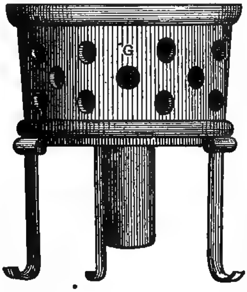
He gives a long and interesting discussion of the effect of light on spirit of turpentine, showing that it increases its specific gravity and its solvent powers, qualities now thought to be due to the action of oxygen, the possibility of which he suggests.

TINGRY'S FURNACE FOR MELTING RESIN.

It is built of fire-clay. The cover of the inner tube, *C*, is of iron, which may be luted to the clay or porcelain tube. The net

D is of brass wire, woven to a brass ring which rests in the conical upper extremity of the tube. The upper part of the furnace is filled with charcoal; the copal, in pieces not larger than a nut, on the wire net. The lower end of the tube *C* is immersed about ¼ in. in water contained in a suitable capsule *F*; or this capsule may contain oil, kept hot by setting the capsule on a plate of hot iron, in which case the melted resin will be at once dissolved by the oil, which will also collect the products of distillation, or such parts as can be liquefied. The laboratory furnace, *A B*, is 17½ ins. in total height, the interior diameter at the top 9½ ins., and at the bottom 7 ins. *G* is a larger furnace, built on an iron tripod. But the inventor says: "I must always insist on the advantage of employing not more than 6 ounces of resin in one operation."





The next author is M. Tripier-Deveaux, who published in 1845 a "Theoretical and Practical Treatise on the Art of Varnish-making." His book has the great merit of having been written by a man engaged commercially in the manufacture and sale of varnish, and he therefore knew what varnishes were in demand and in successful use. He devoted his time chiefly to varnishes composed of resins dissolved in alcohol and in turpentine, and contributed considerably to the accuracy of our knowledge of these; but he also made oleo-resinous varnishes, in which branch he shows most advancement in preparing oil with driers.

In 1866 M. Henri Violette published a treatise, entitled a "Practical Guide for the Manufacture of Varnish," valuable from a historical point of view, but apparently not the work of a practical manufacturer. He gave much more careful description of the various resins, etc., than any of his predecessors, and collected what chemical and other scientific information was at that time accessible to him. His detailed accounts of the preparation of drying oils with litharge and oxide of manganese are of interest; but evidently at that time the making of oleo-resinous varnishes was not in a very advanced state in France. We know from other sources that these varnishes were more extensively made in England at that time, and probably also in the United States; but we have no books of importance on the subject in English, as the English and American makers tried to keep their processes secret.

In Germany the most notable early treatise was that of Dreme, a book similar to those of Watin and Tingry. It was published in 1821 at Brünn. An interesting book on encaustic painting by Fernbach ("Die enkustische Malerei") was published at Munich in 1845.

Mention should also be made of a paper which received a gold medal from the Society of Arts, London, published in Vol. 49 of their Transactions, by Mr. J. Wilson Neil, which gives a detailed account of the actual operation of melting the resin and combining it with oil and turpentine. It is interesting from a historical point of view, but contains nothing essentially novel, and very little that is practised now. It is to be found, practically in full, in Ure's "Dictionary of the Arts and Sciences," which is to be found in almost every collection of technical books.

Within the last half-century several books on varnish have appeared, and some, of notable merit, on pigments. Some of these have been mentioned in preceding chapters of this book.

One of the most serious difficulties of the subject is that in different countries different names are given to the same resin, and the same name to different resins. Violette, for instance, describes under the name of East Indian Copal the resin now known in England and America as Zanzibar, and he describes under the name Zanzibar a soft, "semi-hard" resin of unknown origin. Animi is a name the value of which can never be known except from the context; and even when we speak of a well-known resin like Kauri it is difficult to properly describe the grade. What is known in the New York market as No. 1 Kauri is decidedly inferior to the resin sold under the same name, for about one-third the present price, twenty years ago. Some of the fine African resins formerly used are now rare, and on the other hand new resins are appearing on the market every year. For these and other similar reasons it is useless to give formulæ for making particular varnishes. Every maker is gradually changing his formulæ continually, and must if he keeps up with the improvements of the art.

The writer has had some thoughts of giving an outline of tne chemical work which has been done on varnishes, but it would be of little use. Chemists who are interested have usually access to the original papers, published in the various chemical journals. Methods of analysis of varnishes and paints are rapidly changing, and are still very unsatisfactory. Up to the present time the ingenuity of the manufacturer has been able to keep ahead of the skill of the analyst. It is to be hoped—and I am glad to believe that there are grounds for hope—that our analytical methods will be greatly improved within a few years. At present every manufacturer depends finally on time and exposure tests; but let a warning be given that paints and varnishes may only be tested under fair conditions, and that the best materials will sometimes give bad tests. If we are testing several varnishes of the same class, and keep repeating the tests often enough, we will finally get a trial in which the best varnish shows the poorest result. The explanation of this is that we do not know, or cannot control, all the conditions of the test. All this is equally true of paints and varnishes.

In writing on this subject it is hard to tell what to put in and what to leave out. If the writer expresses too copiously his own experience, the technical details will interest only those who are themselves engaged in like work, and who may be presumed to have as much knowledge of the subject as himself;

and these observations will in a few years be out of date in any case. The general principles involved, and the established and approved methods, are the essential things. These may be comprehended by those who will give the subject the attention it deserves. Painting is an Art. Whether our interest in it is as a fine art or an industrial art, the technical principles are the same; and it is as old as civilization itself. Its practitioners can show an unbroken descent from "the early dusk and dawn of time." They may feel, like all who dignify an art by faithful and intelligent service, that

> "The gods hear men's hands before their lips,
> And heed beyond all crying and sacrifice
> Sight of things done and noise of laboring men."

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